Keysight Technologies B1500A Semiconductor Device Analyzer

KEYSIGHT TECHNOLOGIES

User's Guide

Notices

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Keysight Technologies
1400 Fountaingrove Parkway
Santa Rosa, CA 95403

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Latest Information

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NOTICE: This document contains references to Agilent Technologies. Agilent's former Test and Measurement business has become Keysight Technologies. For more information, go to **www.keysight.com.**

COMPLIANCE WITH GERMAN NOISE REQUIREMENTS

This is to declare that this product is in conformance with the German Regulation on Noise Declaration for Machines
(Lärmangabe nach der Maschinenlärminformation-Verordnung -3.GSGV Deutschland).

- **Herstellerbescheinigung**

  GERÄUSCHEMISSION

  Lpa < 70 dB

  am Arbeitsplatz

  normaler Betrieb

  nach DIN 45635 T. 19

- **Manufacturer's Declaration**

  ACOUSTIC NOISE EMISSION

  Lpa < 70dB

  operator position

  normal operation

  per ISO 7779

South Korean Class A EMC declaration

This equipment is Class A suitable for professional use and is for use in electromagnetic environments outside of the home.

A급 기기

(업무용 방송통신기자재)

이 기기는 업무용(A급) 전자파적합기기로서 판매자 또는 사용자는 이 점을 주의하시기 바라며, 가정외의 지역에서 사용하는 것을 목적으로 합니다.

Safety Summary

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual may impair the protections provided by the instrument. In addition, it violates safety standards of design, manufacture, and intended use of the instrument. Keysight Technologies assumes no liability for customer's failure to comply with these requirements.

Product manuals may be provided on CD-ROM or in printed form. Printed manuals are an option for many products. Manuals may also be available on the Web. Go to www.keysight.com and type the product model number in the Search field at the top of the page.

NOTE

Do not use this instrument in any manner not specified by the manufacturer. The protective features of this instrument may be impaired if it is used in a manner not specified in the operation instructions.

This instrument is an INDOOR USE product.

This instrument complies with INSTALLATION CATEGORY II for mains input and INSTALLATION CATEGORY I for measurement input terminals, and POLLUTION DEGREE 2 defined in IEC 61010-1.

If an instrument is marked CAT I (IEC Measurement Category I), or it is not marked with a measurement category, its measurement terminals must not be connected to line-voltage mains.

- *DANGEROUS PROCEDURE WARNINGS*

  Warnings, such as example below, shall be complied. Procedures throughout in this manual prevent you from potentially hazard. Their instructions contained in the warnings must be followed.

WARNING

Hazardous voltage, instrument maximum output voltage may appear at the measurement terminals (Force, Guard, and Sense) if Interlock terminal is closed. Open the Interlock terminal when the measurement terminals are accessible. Voltage applied to the terminals will be limited up to ±42 V.

Do not work the interlock function intentionally in order to bring the output voltage to the safe level. While the high voltage indicator is lit, the dangerous voltage by the output voltage or the residual charge appears on the measurement terminal.

- *BEFORE APPLYING POWER*

  Verify that all safety precautions are taken. Make all connections to the instrument before applying power. Note the instrument's external markings described under “Safety Symbols”.

- *GROUND THE INSTRUMENT*

  This is Safety Class I instrument. To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The power terminal and the power cable must meet International Electrotechnical Commission (IEC) safety standards.

- *DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE*

  Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

- *DO NOT REMOVE COVERS*

  No operator serviceable parts inside. Refer servicing to qualified personnel. To prevent electrical shock do not remove covers.

- *IN CASE OF DAMAGE*

  Instruments that appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel. Return the instrument to a Keysight Technologies sales or service office for services and repair to ensure that safety features are maintained.

- *USE ONLY THE SPECIFIC ACCESSORIES*

  Specific accessories satisfy the requirements for specific characteristics for using the instrument. Use the specific accessories, cables, adapters, and so on for safety reasons.

Safety Symbols

The general definitions of safety symbols used on equipment or in manuals are listed below.

Direct current.

Alternating current.

Earth (ground) terminal.

Protective conductor terminal. For protection against electrical shock in case of a fault. Used with field wiring terminals to indicate the terminal which must be connected to ground before operating equipment.

Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.

Grounded terminal which indicates the earth potential.

On supply.

Off supply.

Standby supply. The equipment will be marked with this symbol is not completely disconnected from AC mains when power switch is in the standby position.

In position of a bi-stable push switch.

Out position of a bi-stable push switch.

Hazardous voltage and potential for electrical shock. Do not touch terminals that have this symbol when the equipment is on.

Hot surface. Avoid contact. Surfaces are hot and may cause personal injury if touched.

Instruction manual symbol. The equipment will be marked with this symbol when it is necessary for the user to refer to the instruction manual.

WARNING **The warning sign denotes a hazard. It calls attention to a procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in injury or death to personal.**

CAUTION The caution sign denotes a hazard. It calls attention to an operating procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the equipment.

CAT I — IEC Measurement Category I

The CE mark shows that the product complies with all applicable European Directives.

The CSA mark is a registered trademark of the Canadian Standards Association.

The RCM mark is a registered trademark of the Australian Communications Authority. This signifies compliance with the Australian EMC Framework Regulations under the terms of the Radio communications Act.

ICES/NMB-001 — This ISM device complies with Canadian ICES-001.
Cet appareil ISM est conforme à la norme NMB-001 du Canada.

ISM GROUP 1 CLASS A — This is the symbol for an Industrial, Scientific and Medical, Group 1 Class A product. (CISPR 11)

Korea's safety and EMC mark

China RoHS - Environmentally Green Product Label

China RoHS - Product with Toxic Substance 40 yr EPUP

CFB — The Chinese mark for paper-based packaging materials; Paperboard and Corrugated Fiberboard

01 PET — Plastic Material Coding Identification

Power Supply and Measurement Safety

- Power Supply Safety

  This instrument can output high currents and voltages. Make sure that the load or device under test can safely handle the output current and voltage. Also, make sure that the connection leads can safely withstand the expected currents and are insulated for the expected voltages.

  The instrument outputs may be connected so as to float relative to earth ground. Isolation or floating voltage ratings are indicated on the instrument, near the output terminal or the Circuit Common terminal. There is the danger of electric shock by touching the floated measurement terminals. Keep in mind it to protect yourself. And it is a reason of using the recommended accessories.

- Voltage/Current Measurement Safety

  Multimeters and other instruments capable of measuring high voltages and currents are subject to specific safety concerns because of the circuits to which they may be connected. To safely use these instruments, you need to understand the markings on the instrument near the input terminals, which include the Protection Limits and the IEC Measurement Category.

- Protection Limits

  Keysight multimeters and other voltage measurement instruments provide protection circuitry to prevent damage to the instrument and to protect against the danger of electric shock, provided the Protection Limits are not exceeded. To ensure safe operation of the instrument, do not exceed the Protection Limits shown on the input terminals.

- Source/Monitor Terminals

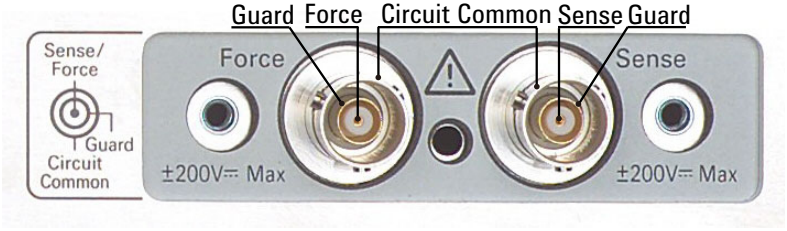
  Source/monitor unit, SMU, can simultaneously perform DC voltage or current output and measurement. Typical SMU has the Force, Guard, Sense, and Circuit Common terminals as shown below. Normally the Force, Guard, and Sense terminals are the same potential. Voltage marked around the terminals indicates the Protection Limits.

  Force and Sense must be connected to a terminal of a device under test for the Kelvin connection which is effective for high current measurement and low resistance measurement. For the non-Kelvin connection to ease the connections, connect Force only. Do not connect Sense. It must be opened.

  Guard should be extended to around the device terminal for reducing leakage current caused by a coaxial cable used. Guard must be never connected to anything at the device side.

  Circuit Common should be connected to shielding of the coaxial cable used.

  The following image is the Kelvin triaxial connector of High Power SMU.



High Voltage Shock Hazard

Keysight B1500A can force dangerous voltages (±200 V for HPSMU and ±100 V for MPSMU/HRSMU) at the Force, Guard, and Sense terminals. To prevent electric shock hazard, the following safety precautions must be observed during the use of Keysight B1500A.

- Use a three-conductor AC power cable to appliance coupler (inlet) and the instrument to an electric ground (safety ground).
- Prepare shielding box which covers interface to a device under test and equipped with interlock circuit that opens when the door is opened.
- Before performing measurement, connect the interlock circuit to the Interlock terminal of this instrument.
- Confirm periodically that the interlock function works normally.
- Before touching the connections of the Force, Guard, and Sense terminals, turn the instrument off and discharge any capacitors of the measurement path. If you do not turn the instrument off, complete “all” of the following items, regardless of any instrument’s settings.
    - Terminate measurement by pressing the Stop key, confirm that the Measurement status indicator is not lit.
    - Confirm that the High Voltage indicator is not lit.
    - Open the shielding box access door (open the Interlock terminal).
    - Discharge any capacitors if the capacitance is connected to an SMU.
- Warn workers in the vicinity of the instrument about hazardous conditions.

Gefahr durch Hochspannung

Von den Geräten Keysight B1500A können Spannungen an den Anschlüssen “Force”, “Guard” und “Sense” von bis zu 200 V ausgehen. Um elektrischem Schlag vorzubeugen, ist bei der Benützung der Geräte Keysight B1500A folgendes zu beachten.

- Verwenden Sie ein dreiphasiges AC-Stromkabel für die Gerätsteckvorrichtung (Eingang) und schließen Sie das Instrument an eine Erdung an (Sicherheitserdung).
- Bereiten Sie das Abschirmungsgehäuse vor, dass die Oberfläche eines zu testenden Geräts abdeckt und mit einem Verriegelungsstromkreis ausgestattet ist, der bei geöffneter Tür unterbrochen wird.
- Vor der Messung verbinden Sie den Verriegelungsstromkreis mit dem Interlock-Anschluss dieses Instruments.
- Prüfen Sie in regelmäßigen Abständen, dass die Verriegelungsfunktion ordnungsgemäß funktioniert.
- Bevor Sie die Verbindungen zu den Anschlüssen “Force”, “Guard” und “Sense” berühren, schalten Sie das Instrument aus und entladen alle Kondensatoren des Messwegs. Wenn Sie das Instrument nicht ausschalten, führen Sie, unabhängig von den Instrumenteinstellungen, alle folgenden Schritte durch.
  - Beenden Sie die Messung, indem Sie auf die Taste “Stop” drücken. Stellen Sie sicher, dass die Statusanzeige “Measurement” nicht leuchtet.
  - Stellen Sie sicher, dass die Anzeige “High Voltage” nicht leuchtet.
  - Öffnen Sie die Tür des Abschirmungsgehäuses (öffnen des Interlock-Anschlusses).
  - Entladen Sie alle Kondensatoren, wenn die Kapazität mit einer SMU verbunden ist.
- Warnen Sie Mitarbeiter in der Umgebung des Instruments vor den Gefahren.

Danger de choc dû à une haute tension

Une tension dangereuse (max. ± pour HPSMU; 200 Vdc, max. ± pour MPSMU/ HRSMU; 100 Vdc) émanant du dispositif Keysight B1500A peut être sortie aux bornes Force, Guard et Sense. Les précautions suivantes doivent être obserées contre commotion électrique accidentelle.

- Utilisez un câble d'alimentation CA à trois conducteurs vers le coupleur secteur (entrée) et branchez l'instrument sur une mise électrique à la terre (prise de terre de sécurité).
- Préparez le boîtier de protection qui couvre l'interface avec le dispositif à tester et équipez-le d'un circuit de sécurité qui s'ouvre lors de l'ouverture d'une porte.
- Avant de procéder aux mesures, connectez le circuit de sécurité à la borne Interlock de l'instrument.
- Vérifiez régulièrement le bon fonctionnement de la fonction de sécurité.
- Avant de toucher les connexions des bornes Force, Guard et Sense, mettez l'instrument hors tension et déchargez tout condensateur du chemin de mesure. Si vous ne mettez pas l'instrument hors tension, effectuez « toutes » les opérations ci-dessous, quels que soient les paramètres de l'instrument.
    - Terminez les mesures en appuyant sur la touche Stop ; vérifiez que l'indicateur d'état Measurement est éteint.
    - Vérifiez que le témoin High Voltage est éteint.
    - Ouvrez la trappe d'accès au boîtier de protection (ouvrez la borne Interlock).
    - Déchargez les éventuels condensateurs si la capacité est connectée à une unité SMU.
- Informez les personnes travaillant à proximité de l'instrument des conditions.

高電圧感電注意

Keysight B1500A の Force、Guard、Sense 端子には、危険電圧が出力されることがあります（HPSMU の場合は最大 ±200 Vdc、MPSMU/HRSMU の場合は最大 ±100 Vdc）。感電事故防止のため、必ず以下の事柄を守ってください。

- 3 極電源ケーブルを使用して本器を接地してください。
- ドアを開くことによって開放されるインターロック回路を装備し、被測定デバイスとのインタフェースを覆うことのできるシールド・ボックスを用意してください。
- 測定を開始する前にはインターロック回路を本器の Interlock 端子に接続してください。
- インターロック機能が正常であることを定期的に確認してください。
- Force、Guard、Sense 端子に繋がる接続部に触れる前には、本器の電源を切断してください。また、測定系のキャパシタを放電してください。電源を切らない場合は、以下の事項を全て実施してください。
    - Stop キーを押して Measurement インジケータが消灯したことを確認してください。
    - 高電圧警告（High Voltage）インジケータが消灯していることを確認してください。
    - シールド・ボックスのドアを開けてください（Interlock 端子を開放してください）。
    - キャパシタが SMU に接続されているならば、キャパシタを放電してください。
- 周囲のほかの作業者に対しても、高電圧危険に対する注意を徹底してください。

Product Stewardship

- Waste Electrical and Electronic Equipment (WEEE) Directive 2002/96/EC

  This product complies with the WEEE Directive (2002/96/EC) marking requirements. The affixed label indicates that you must not discard this electrical/ electronic product in domestic household waste.

  Product Category: With reference to the equipment types in the WEEE directive Annex 1, this product is classified as a “Monitoring and Control instrumentation” product.

  Do not dispose in domestic household waste.

  To return unwanted products, contact your local Keysight office or visit the following website for more information.

  www.keysight.com/environment/product/

- LCD Fluorescent Lamp

  Certain products sold by Keysight contain a liquid crystal display (LCD); backlighting for the LCD is provided by a fluorescent lamp which contains mercury, and must be managed, recycled, and/or disposed in accordance with all applicable laws, ordinances and regulations.

  For information on how to recycle or dispose of the fluorescent lamp contained in your own product, visit the following website.

  http://www.keysight.com/environment/mercury.shtml

  If you live in the U.S., also visit the following websites.

  http://www.lamprecycle.org

  http://www.eiae.org

  If you have additional questions, please visit the following website.

  http://www.keysight.com/go/contactus

- Perchlorate Information

  Perchlorate Material - special handling may apply. Visit the following website.

  http://www.dtsc.ca.gov/hazardouswaste/perchlorate/

  Equipment's real-time clock battery or coin cell battery may contain perchlorate and may require special handling when recycled or disposed of in California.

Precautionary Statement

Keysight B1500A Semiconductor Device Analyzer operates in the Microsoft Windows environment. Keysight B1500A requires Keysight EasyEXPERT software, a specially-designed Windows application program.

- About guarantee and support for Keysight B1500A

  Keysight Technologies guarantees and supports the performance of Keysight B1500A for the same condition as the preload condition when shipped from the factory.

- About updating Keysight EasyEXPERT and the Windows Update

  Keysight Technologies confirms the operation of Keysight EasyEXPERT patch programs and important Windows security patches, and provides recommended update information. Visit Keysight B1500A support site, download the patches, and perform the software update.

- About Windows application programs and peripherals (including driver)

  Using commercial products on Keysight B1500A is your responsibility. Keysight Technologies cannot provide compatibility information for commercial products. If problems arise, perform Keysight B1500A system recovery.

- About servicing

  Bench repair service is available at your nearest Keysight Technologies service center. Be aware that the B1500A configuration might be updated to the latest one without notice because of support issues.

  The internal hard disk drive (HDD) might be initialized during servicing. If peripherals are connected, they will be removed.

  When Keysight B1500A is returned, the internal HDD might be initialized. Peripherals will be returned separately.

- Other notes

  - Back up the internal HDD to prevent loss of data by accident or failure.
  - Protect Keysight B1500A from computer viruses.
  - If you connect Keysight B1500A to the network, take care to protect it from computer virus.

Working in Comfort

To optimize your comfort and productivity, it is important that you set up your work area correctly and use your instrument properly. With that in mind, we have developed some set-up and use recommendations for you to follow based on established ergonomic principles. Improper and prolonged use of keyboards and input devices are among those tasks that have been associated with repetitive strain injury (RSI) to soft tissues in the hands and arms. If you experience discomfort or pain while using the instrument, discontinue use immediately and consult your physician as soon as possible. For more information on RSI you may wish to consult the *About Repetitive Strain* Injury section. Please study the recommendations described below. Included there are references to relevant parts of international standards, regulations and guidelines, such as ISO 9241 and the European Community Display Screen Equipment directive. You may also wish to consult your employer's human resources department or other relevant departments for guidance specific to your company.

About Repetitive Strain Injury

Because your comfort and safety are our primary concern, we strongly recommend that you use the instrument in accordance with established ergonomic principles and recommendations. Scientific literature suggests that there may be a relationship between injury to soft tissues -especially in the hands and arms- and prolonged improper use of keyboards or other equipment requiring repeated motions of the hands and forearms. This literature also suggests that there are many other risk factors that may increase the chance of such injury, commonly called Repetitive Strain Injury.

What is RSI?

Repetitive Strain Injury (RSI -also known as cumulative trauma disorder or repetitive motion injury) is a type of injury where soft tissues in the body, such as muscles, nerves, or tendons, become irritated or inflamed. RSI has been a reported problem for those who perform repetitive tasks such as assembly line work, meatpacking, sewing, playing musical instruments, and computer work. RSI also has been observed in those who frequently engage in activities such as carpentry, knitting, housework, gardening, tennis, windsurfing and lifting children.

What causes RSI?

The specific causes of RSI have not been established. Nevertheless, the incidence of RSI has been associated with a variety of risk factors, including:

- Too many uninterrupted repetitions of an activity or motion.
- Performing an activity in an awkward or unnatural posture.

- Maintaining static posture for prolonged periods.
- Failing to take frequent short breaks.
- Other environmental and psychosocial factors.

In addition, there have been reports associating the occurrence of RSI with the use of keyboards, mice, and other input devices. Also, certain medical conditions, such as rheumatoid arthritis, obesity and diabetes, may predispose some people to this type of injury.

What if I experience discomfort?

If you are experiencing any discomfort, seek professional medical advice immediately. Typically, the earlier a problem is diagnosed and treated, the easier it is to resolve.

Mice and Other Input Devices

Various aspects of using mice and other input devices may increase your risk of discomfort or injury. Observing the following recommendations may reduce that risk.

- Try to keep your hand, wrist, and forearm in a neutral position while using your mouse or other input device.
- If you use your thumb to rotate the ball on a trackball or spaceball, keep it in a relaxed, natural shape, and maintain a neutral posture in your hand, wrist, and forearm.
- Hold the mouse gently by draping your fingers over it. Keep your hand relaxed and fingers loose. Do not grip the mouse tightly.
- It takes very little pressure or force from your fingers to activate the buttons or scroll wheel on your mouse, scrolling mouse, trackball, or other input device. Using too much force can place unnecessary stress on the tendons and muscles in your hands, wrists, and forearms.
- If you are using a scrolling mouse, be sure to keep your fingers and hand in a relaxed, neutral position when activating the scroll wheel. Also, this type of mouse features software that can minimize the number of mouse movements or button clicks.
- When using a mouse, trackball, or other input device, position it as close to the keyboard as possible, and keep it at the same level as you do not have to stretch while using it.
- Be sure to keep your mouse and trackball clean. Regular removal of accumulated dust and dirt helps ensure proper tracking and reduces unnecessary hand and wrist motions.

In This Manual

This manual describes the product overview and installation information of Keysight Technologies B1500A. This manual consists of the following chapters:

- Chapter 1, Getting Started

  This chapter describes basic operations of Keysight B1500A.

- Chapter 2, Introduction

  This chapter describes basic features of Keysight B1500A.

- Chapter 3, Installation

  This chapter describes installation, device connection, and maintenance.

- Chapter 4, Specifications

  This chapter describes specifications of Keysight B1500A.

- Chapter 5, Accessories and Options

  This chapter describes accessories and options of Keysight B1500A.

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5. Accessories and Options

1 Getting Started

KEYSIGHT TECHNOLOGIES

This chapter describes the basic operations of Keysight B1500A. Before learning the product details, let's try to use the B1500A briefly. The operations need the B1500A, power cable, and USB keyboard only (USB mouse and stylus pen are optional). Keysight B1500A also requires Keysight EasyEXPERT software as its graphical user interface.

During the operations, you will not connect device under test. Open all measurement terminal.

This chapter consists of the following sections.

- "To Turn On/Off B1500A"
- "To Launch EasyEXPERT"
- "To Use Tracer Test Mode"
- "To Use Application Test Mode"
- "To Use Classic Test Mode"
- "To Perform Measurement"
- "To Use Analysis Tools"

NOTE

If you use the B1500A at the first time

If this is the first time to turn Keysight B1500 on after the delivery, you need to perform the initial setup of the B1500. See "Inspection and Installation" on page 3-7. After the initial setup and if no users are added, you can automatically logon as "Keysight B1500 User" account without password.

To Turn On/Off B1500A

NOTE

When turning the B1500A on

Open the measurement terminals at the device side when turning the B1500A on. Also disconnect the device from the measurement terminals and open the measurement terminals after the test. If you leave the connection with the device, the device may be damaged by unexpected operations or charge-up of measurement cables.

NOTE

If Start EasyEXPERT button is not displayed

Select All Programs > Start EasyEXPERT from the Start menu. The Start EasyEXPERT button will be displayed.

NOTE

Automatic start function

If the automatic start function is on, EasyEXPERT is launched within the B1500A boot up process. If the function is off, EasyEXPERT is not launched and the Start EasyEXPERT button is displayed.

To turn the automatic start function off, use the Start EasyEXPERT window displayed by the File > Exit menu on the EasyEXPERT main screen. And remove the check from the Option > Auto Start of EasyEXPERT menu.

NOTE

If EasyEXPERT does not run

Launch “Keysight Connection Expert” by using the icon on Windows taskbar. And check the USB0 connection status displayed in “Instrument I/O on this PC” area.

USB0 connection status display example:

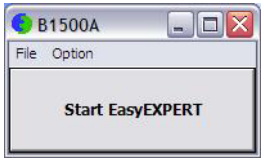
```
USB0
 + B1500A(USB0::2391::1::0001::0::INSTR)
    + agb1500a
    + UsbDevice1
```

If “agb1500A” and “UsbDevice1” are not listed, add them by using “Add VISA Alias” in the right-button-menu on “B1500A (USB0:: . . ::INSTR)”. If the problem still remains, perform Keysight B1500 system recovery. To perform recovery, see Keysight EasyEXPERT *User’s Guide*.

To Turn B1500A On

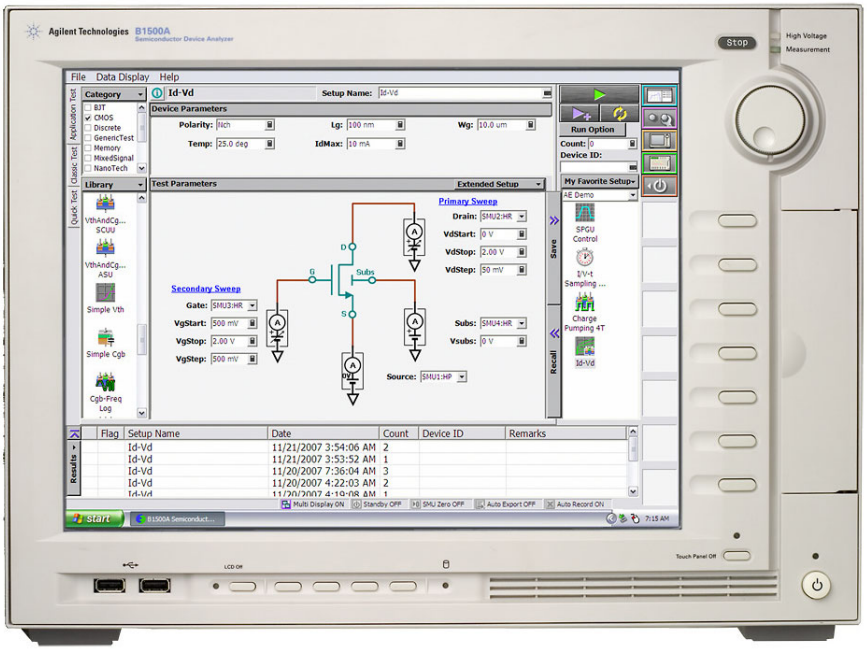
1. Connect the power cable from Keysight B1500A to an AC power outlet.
2. Connect the USB keyboard to the B1500A. Optionally, connect the USB mouse to the B1500A.
3. Press the Standby switch (lower right corner of the front panel). Windows, measurement module initialization, and self-calibration will start. For the Windows logon screen, log on Windows.

   After logging on, the Start EasyEXPERT button will be displayed on the screen, or EasyEXPERT will be launched if the automatic start function is on.



To Turn B1500A Off

Press the Standby switch (lower right corner of the front panel). Windows will be shutdown and the B1500A will become the standby state.



NOTE

Keysight B1500A has the following front panel user interface.

- Stop

  Stops the present measurement or source output immediately.

- Rotary knob

  Rotating the knob moves the marker on the graph window, or increases/decreases/changes the value in the active entry field.

  Pressing the knob sets or enters the value.

- Softkeys

  Seven softkeys are available. Used to select one for the entry field specified or the dialog box. They are also used to recall the test definitions (pre-defined test setups).

- Touch Panel Off

  Enables or disables the touch screen operation.

- Standby switch

  Turns the B1500A on. Pressing the button in the ON state makes the B1500A in the standby state.

- LCD Off

  Enables or disables the LCD panel. LED lights when the LCD is disabled.

- +, -, Set, Cancel

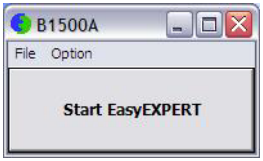
  Four keys are available for adjusting brightness. Use + and - to adjust it and then press *Set* to fix it. Pressing *Cancel* instead of *Set* cancels the adjustment.

Keysight B1500A also requires Keysight EasyEXPERT software as its graphical user interface. You can operate Keysight EasyEXPERT by using the touch panel. Use your fingers, stylus pen, and so on for the touch panel operation. The USB keyboard and the USB mouse are also available for operating the EasyEXPERT.

To remove USB devices from the B1500A, use “Safely Remove Hardware” on Windows taskbar. If it is not used, the B1500A may cause the internal USB communication error. If the error occurs, turn the B1500A off and disconnect the power cable from the B1500A. Leave it about 30 seconds before rebooting the B1500A, and connect the power cable again, and then turn the B1500A on.

To Launch EasyEXPERT

1. If the automatic start function is off, the Start EasyEXPERT button is displayed. Click the button and wait until the EasyEXPERT main screen or workspace selection screen is displayed.



NOTE

Workspace is the space created in Keysight B1500A's internal hard disk drive, and is used to store the test setup, test result data, and so on. The workspace can be created and allocated for each user.

2. If this is the first time to start the EasyEXPERT, or if no workspace exists, a workspace will be created automatically.

   Skip to "To Use Tracer Test Mode" on page 1-10, "To Use Application Test Mode" on page 1-12, or "To Use Classic Test Mode" on page 1-14.

3. If only one workspace exists, the B1500A displays the screen as shown in Figure 1-1.

   Skip to "If Only One Workspace Exists" on page 1-7.

4. If two or more workspaces exist, the B1500A displays the screen as shown in Figure 1-3.

   Skip to "To Select Workspace" on page 1-9.

If Only One Workspace Exists

For the screen as shown in Figure 1-1, perform the following steps.

- If you do not want to create a workspace, select the *Yes* radio button and click OK. Skip to "To Use Tracer Test Mode" on page 1-10, "To Use Application Test Mode" on page 1-12, or "To Use Classic Test Mode" on page 1-14.
- If you want to create a workspace, select the *No, I want to start a new session.* radio button and click Next. The B1500A displays the screen as shown in Figure 1-2. Skip to "To Create Workspace" on page 1-8.
- If you want to manage workspaces, select the *No, I want to manage Workspaces.* radio button and click Next. The B1500A displays the screen as shown in Figure 1-3. Skip to "To Select Workspace" on page 1-9.

Figure 1-1 **If Only One Workspace Exists**

You have used this instrument previously. Do you want to continue working on the previous setups and data ?
Yes, I want to continue working on the previous setups and data.
No, I want to start a new session.
Note: Even if you start a new session, you can still access setups and data from previous sessions.
No, I want to manage Workspaces.
Next
Work on the same setups and data in the next time.

NOTE

Work on the same setups and data in the next time

If this check box is checked, the workspace selection screen will be skipped at the next startup and EasyEXPERT will be launched with the workspace used at the last operation. To perform this setup again, click the File > Close Workspace menu on the EasyEXPERT main screen.

To Create Workspace

For the screen as shown in Figure 1-2, perform the following steps. To cancel creating workspace, click Prev.

1. Enter the name of the new workspace into the above-entry field.

   Check *Allow other users to access this workspace* box if you want to create a public workspace that is opened for all users.

2. If you are the owner of the existing workspace, you can change the name of the existing workspace.

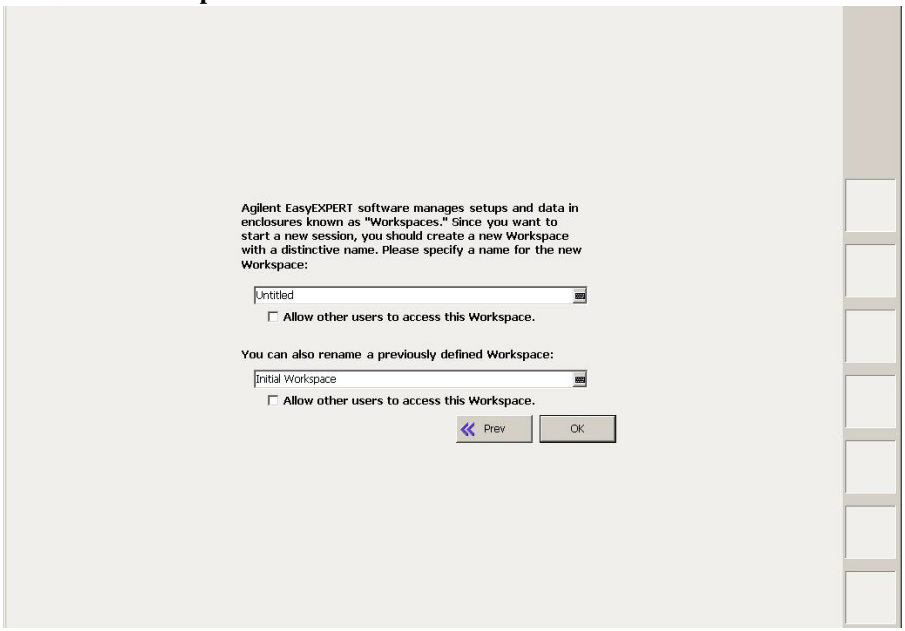
   If you want to rename the existing workspace, enter the name into the below-entry field.

   Check *Allow other users to access this workspace* box if you want to set it to a public workspace that is opened for all users.

3. Click OK.

Skip to "To Use Tracer Test Mode" on page 1-10, "To Use Application Test Mode" on page 1-12, or "To Use Classic Test Mode" on page 1-14.

Figure 1-2 **To Create Workspace**


Agilent EasyEXPERT software manages setups and data in enclosures known as "Workspaces." Since you want to start a new session, you should create a new Workspace with a distinctive name. Please specify a name for the new Workspace:
Untitled
Allow other users to access this Workspace.
You can also rename a previously defined Workspace:
Initial Workspace
Allow other users to access this Workspace.
Prev
OK

To Select Workspace

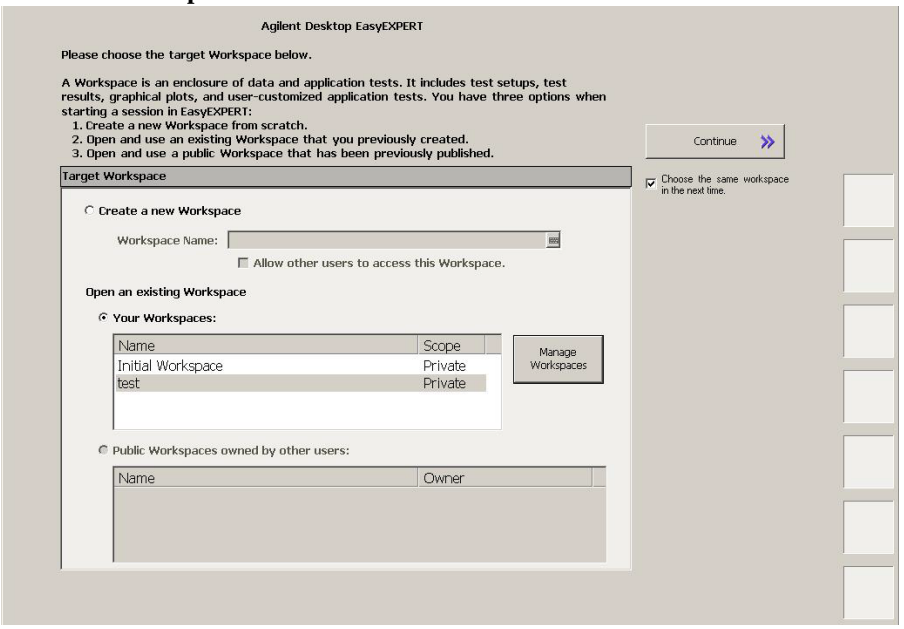
For the screen as shown in Figure 1-3, perform the following steps. This example selects the workspace named as *test* that is a private workspace.

1. Select *Your Workspaces* radio button.
2. Select *test* and click Continue.

Skip to "To Use Tracer Test Mode" on page 1-10, "To Use Application Test Mode" on page 1-12, or "To Use Classic Test Mode" on page 1-14.

If you want to manage workspaces, click the *Manage Workspaces* button. See *Keysight EasyEXPERT User's Guide*.

Figure 1-3 **To Select Workspace**


Agilent Desktop EasyEXPERT
Please choose the target Workspace below.
A Workspace is an enclosure of data and application tests. It includes test setups, test results, graphical plots, and user-customized application tests. You have three options when starting a session in EasyEXPERT:
1. Create a new Workspace from scratch.
2. Open and use an existing Workspace that you previously created.
3. Open and use a public Workspace that has been previously published.
Continue
Choose the same workspace in the next time.
Target Workspace
Create a new Workspace
Workspace Name:
Allow other users to access this Workspace.
Open an existing Workspace
Your Workspaces:
Name
Scope
Initial Workspace
Private
test
Private
Manage Workspaces
Public Workspaces owned by other users:
Name
Owner

NOTE

Choose the same Workspace in the next time

If this check box is checked, the workspace selection screen will be skipped at the next startup and EasyEXPERT will be launched with the workspace used at the last operation. To perform this setup again, click the File > Close Workspace menu on the EasyEXPERT main screen.

To Use Tracer Test Mode

The following procedure performs the tracer test setup.

1. Click the Tracer Test tab on the main screen. The tab is in the leftmost column on the screen. The I/V Trace screen is displayed. See Figure 1-4.
2. Set the channels at the field below the graph as shown in Table 1-1.
3. Set the measurement condition at the right field of the graph as shown in Table 1-3.
4. Set the graph display condition at the field below the graph as shown in Table 1-2.

To enter the value, use the USB keyboard or the screen/numeric keyboard opened by clicking the right button of the entry field.

To start measurement, click for the single measurement or for the repeat measurement.

If the Stop field is highlighted, the range of measurement and graph display can be changed by using the rotary knob during the repeat measurement.

Table 1-1 **I/V Trace Channel Setup**

Unit	V Name	I Name	Mode [a]	Function
SMU1	V1	I1	V	VAR1
SMU2	V2	I2	V	CONST

a. Channel output mode. Set I or IPULSE for the current output and voltage measurement. Set V or VPULSE for the voltage output and current measurement.

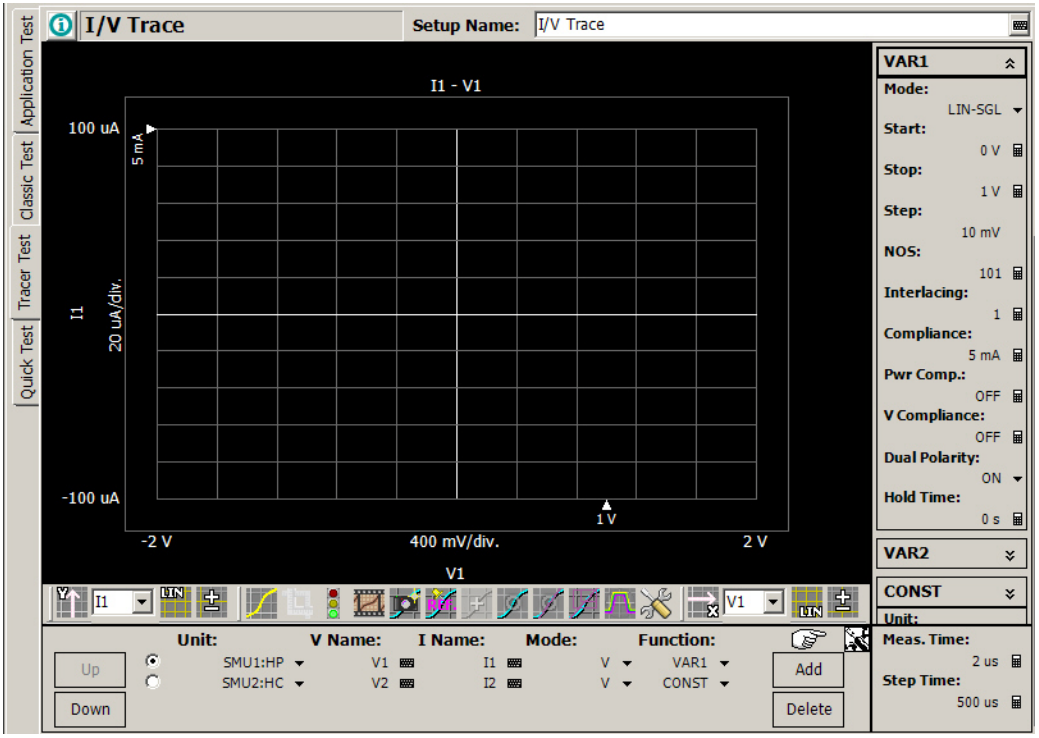
Table 1-2 **I/V Trace Graph Setup**

	Name	Scale			Name	Scale	
Y ↑	I1	LIN	±	→ X	V1	LIN	±

Table 1-3 **I/V Trace Measurement Setup**

VAR1		CONST	
Mode	LIN-SGL	**Unit**	SMU2
Start	0 V	**Source**	0 V
Stop	1 V	**Compliance**	5 mA
Step	10 mV		
NOS	101		
Interlacing	1		
Compliance	5 mA		
Pwr Comp.	OFF	**Meas. Time**	2 us
Dual Polarity	ON	**Step Time**	500 us

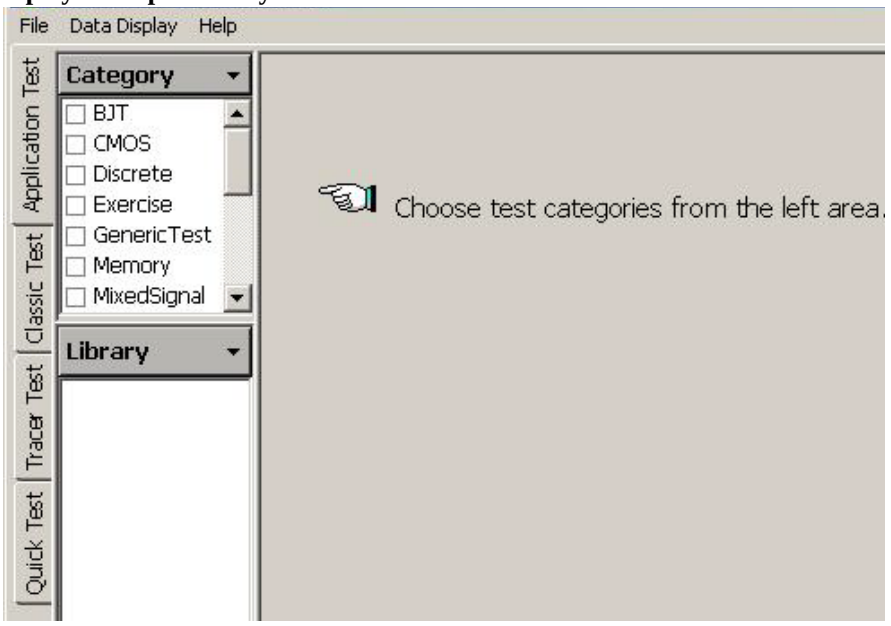
Figure 1-4 **Display Example of I/V Trace Screen**



To Use Application Test Mode

For the screen as shown in Figure 1-5, perform the following procedure.

Figure 1-5 **Display Example of EasyEXPERT Main Screen**



1. Click the Application Test tab on the main screen. The tab is in the leftmost column on the screen.
2. Set the Category field. For example, check the CMOS only. The Library field lists the test definitions.
3. Select a test definition at the Library field. For example, click the *Id-Vg* and *Select* button sequentially. The screen changes the display as shown in Figure 1-6.
4. Change the measurement conditions at the Test Parameters field.

   The following example changes the voltage sweep output.

   a. Set VgStart to `0 V` and VgStep to `0.2 V`.

   b. Set VsubsStep to `-1.0 V`.

To enter the value, use the USB keyboard or the screen/numeric keyboard opened by clicking the right button of the entry field.

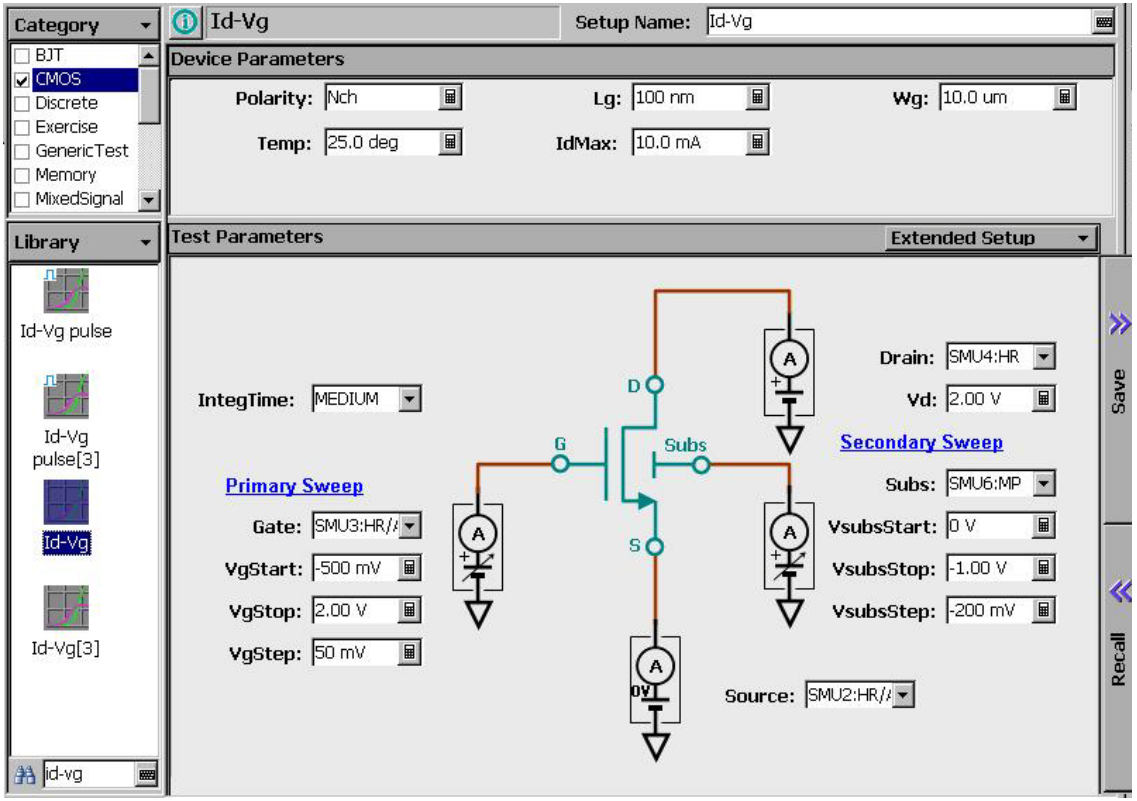
See "To Perform Measurement" on page 1-16 to start measurement.

NOTE

Test Definitions

Test definitions are the built-in test setups that have been defined and stored in the EasyEXPERT as the application library. The EasyEXPERT contains more than two hundred test definitions. You can execute the test without modifications. Also you can create your own test setup/definition by making any changes. All furnished test definitions are just sample. Keysight Technologies is NOT LIABLE for any damages caused by the samples.

Figure 1-6 Display Example of Application Test Setup Screen



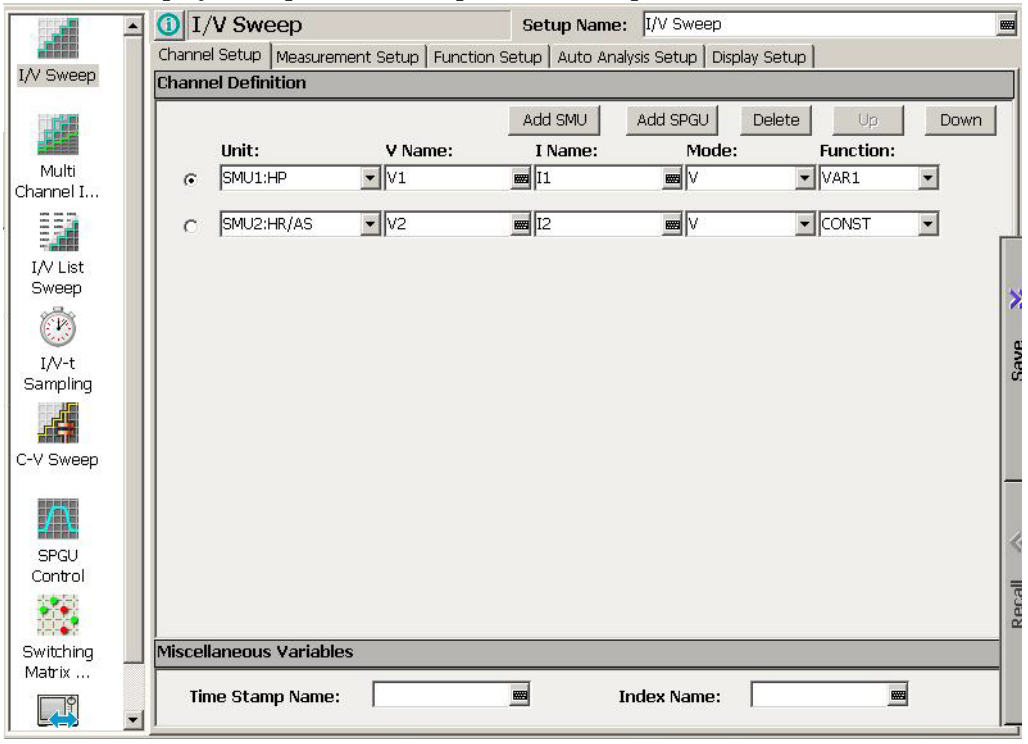
To Use Classic Test Mode

The following procedure performs the I/V Sweep classic test setup.

1. Click the Classic Test tab on the main screen. The tab is in the leftmost column on the screen.
2. Click I/V Sweep and Select button sequentially. The I/V Sweep Channel Setup screen is displayed. See Figure 1-7.
3. Set the Channel Setup parameters as shown in Table 1-4.
4. Click the Measurement Setup tab and set the parameters as shown in Table 1-5.
5. Click the Display Setup tab and set the parameters as shown in Table 1-6.

To enter the value, use the USB keyboard or the screen/numeric keyboard opened by clicking the right button of the entry field.

Figure 1-7 Display Example of I/V Sweep Channel Setup Screen



See "To Perform Measurement" on page 1-16 to start measurement.

Table 1-4 **I/V Sweep Channel Setup**

Unit	V Name	I Name	Mode [a]	Function
SMU1	V1	I1	V	VAR1
SMU2	V2	I2	V	CONST

a. Channel output mode. Set I or IPULSE for the current output and voltage measurement. Set V, VPULSE, or COMMON for the voltage output and current measurement.

Table 1-5 **I/V Sweep Measurement Setup**

VAR1		Timing		Constants	
Unit	SMU1	**Hold**	0 s	**Unit**	SMU2
Name	V1	**Delay**	0 s	**V Name**	V2
Direction	Single			**I Name**	I2
Linear/Log	LINEAR			**Mode**	V
Start	0 V			**Source**	0 V
Stop	1 V			**Compliance**	100 mA
Step	10 mV				
No of Step	101				
Compliance	100 mA				
Pwr Comp	OFF	**Sweep**	CONTINUE AT ANY		**status**

Table 1-6 **I/V Sweep Display Setup**

	Name	Sharing	Scale	Min	Max
X	V1	(None)	Linear	0 V	1 V
Y1	I1	(None)	Linear	-1 pA	1 pA

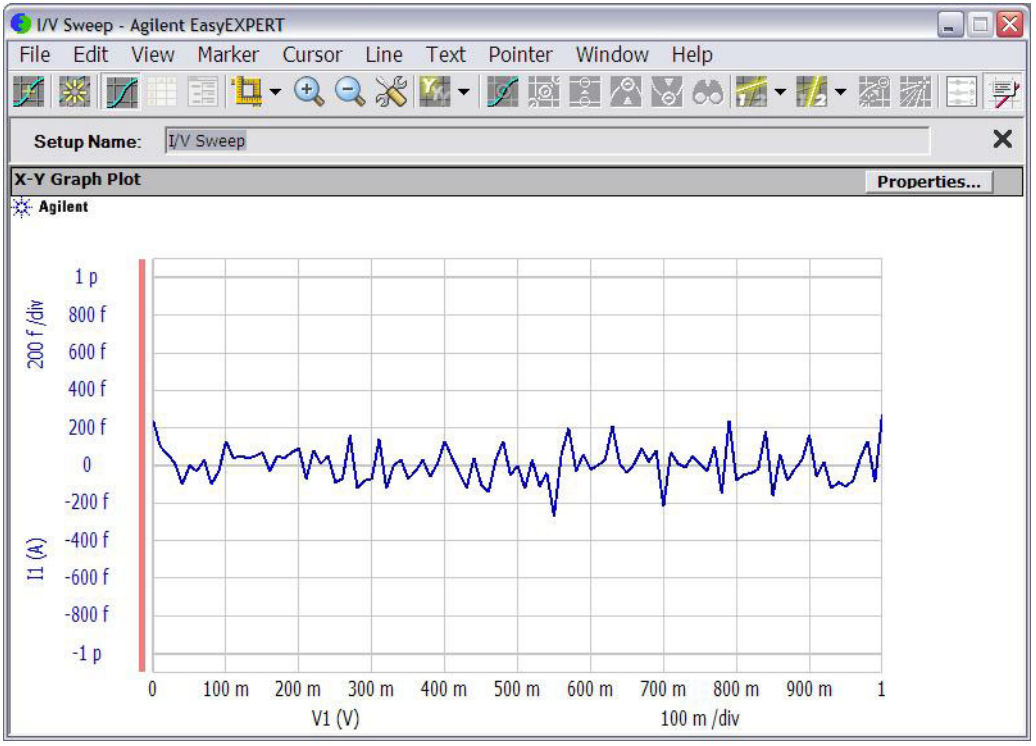
To Perform Measurement

1. Click the Single button (upper right on the main screen) to start measurement. This opens the Data Display window and starts a single sweep measurement.

   After the measurement, the measurement data is displayed on the Data Display window. For the measurement after performing "To Use Classic Test Mode" on page 1-14, you will have the test result as shown in Figure 1-8. This is the leakage current measurement result because all measurement terminal is opened for performing the procedures described in this chapter.

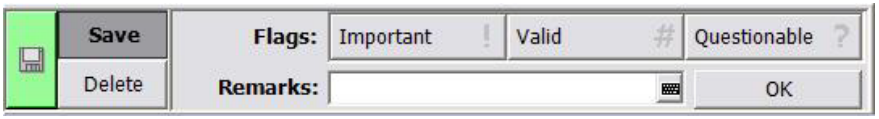
2. If the automatic data record function has been set to ON (Auto Record ON), Test Result Editor appears on the lower area of the screen when the measurement is completed. See "To Use Test Result Editor" on page 1-17.

Figure 1-8 Display Example of Data Display Window



To Use Test Result Editor

The Test Result Editor provides the following GUI to set a flag and remarks to the test result record.



- Save button and Delete button

  Divides test records into groups, Save and Delete.

  Test records in Save-group are always listed in the lower area of the EasyEXPERT main screen.

  Test records in Delete-group can be listed when Results > Filter > Show Deleted Data is checked.

- Flags buttons

  The following buttons are available. You can set one of the following flags.

  - Important ! button

    Sets the important flag (!) to the test result record.

  - Valid # button

    Sets the valid flag (#) to the test result record.

  - Questionable ? button

    Sets the questionable flag (?) to the test result record.

- Remarks field

  You can enter characters into this field. The characters will be recorded as the Remarks value of the test result record.

- OK button

  Applies the setup on the Test Result Editor, and closes this dialog box.

To Use Analysis Tools

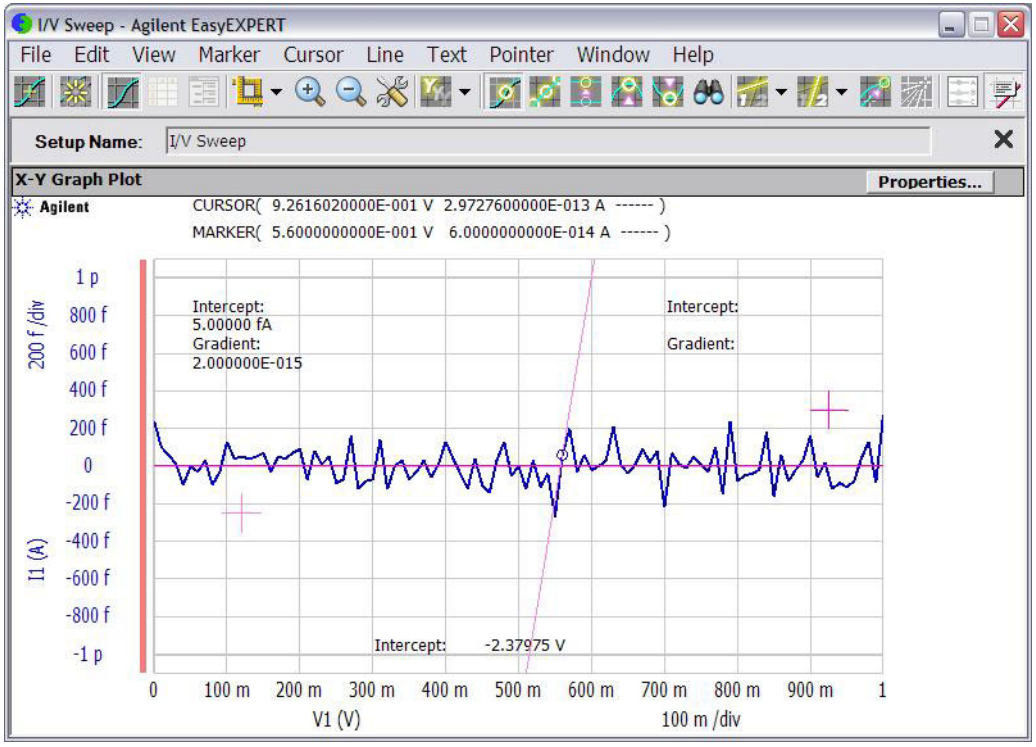
The Data Display window provides several analysis functions.

- View menu: used to adjust the graph scale.
- Marker menu: used to display and control the marker.
- Cursor menu: used to display and control the cursor.
- Line menu: used to display and control the lines.

When the marker, cursor, and lines are effective, their parameters are also displayed on the X-Y Graph Plot area.

Figure 1-9 is an example displaying marker, tangent line, and regression line on the test result graph shown in Figure 1-8. You can read position of the marker and the active cursor, and interrupt and gradient of the active line.

Figure 1-9 Display Example of Analysis Tools



2 Introduction

KEYSIGHT TECHNOLOGIES

This chapter describes the basic functions and features of Keysight B1500A Semiconductor Device Analyzer, and consists of the following sections:

- "Overview"
- "Front View"
- "Rear View"
- "Measurement Modules"

NOTE

Application Library

Keysight B1500A has installed Keysight EasyEXPERT software as the user interface. The EasyEXPERT contains an application library that is a set of test definitions. The application test can be performed by selecting a test definition and setting the test condition for the actual DUT (device under test).

All test definitions are just sample. If the samples damage your devices, Keysight Technologies is NOT LIABLE for the damage.

NOTE

Furnished Sample Programs (Utility)

The following sample programs are stored in the following folder.

- <program folder>\Agilent\B1500\EasyEXPERT\Utilities\

  Prober control programs

  sleep.exe program

- <program folder>\Agilent\B1500\EasyEXPERT\415xC\Conversion\

  4155/4156 setup file converter

- <program folder>\Agilent\B1500\EasyEXPERT\IC-CAP Support\MDM\

  MDM file converter for IC-CAP users

Where, <program folder> is as follows. Then, <system drive> is the drive the EasyEXPERT has been installed.

For Windows 7 64 bit version, <system drive>:\Program Files (x86)

For Windows 7 32 bit version, Vista, or XP, <system drive>:\Program Files

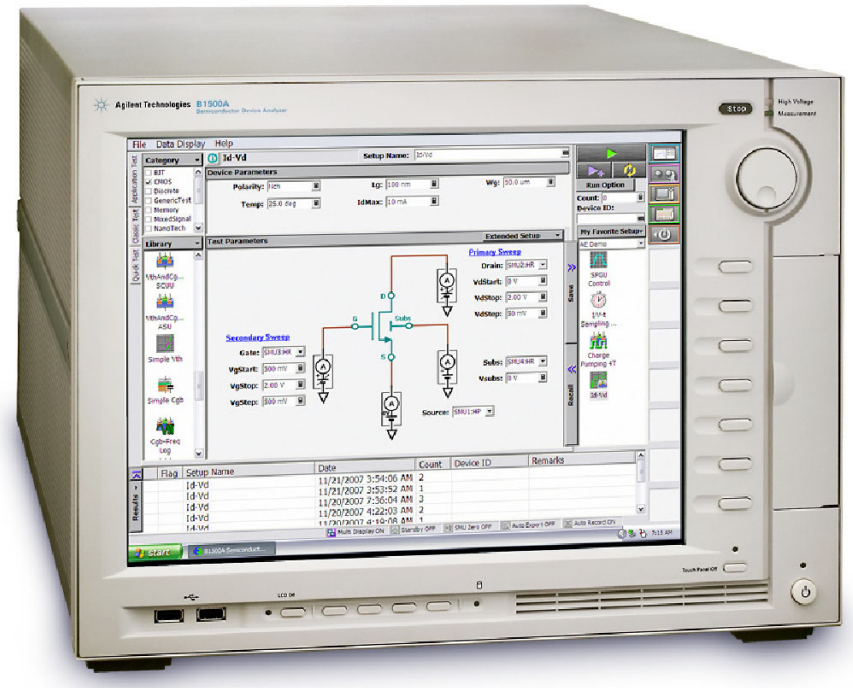
For more details of programs, see Keysight EasyEXPERT User's Guide.

Overview

Keysight B1500A Semiconductor Device Analyzer is the new generation one box solution for the semiconductor device DC/AC parametric measurement and analysis application. Keysight B1500A provides the DC voltage/current output capability, DC voltage/current measurement capability, and AC signal output and impedance measurement capability. So you can perform a current-voltage sweep measurement and a capacitance-voltage sweep measurement for example by one instrument.

Keysight B1500A also provides an intuitive graphical user interface, touch screen LCD panel, keyboard, and mouse for easy and effective measurement and analysis on the Windows environment. You can analyze a measurement result characteristics graph for example by using several tools such as markers, cursors, and lines.

Also, in the GPIB remote control mode, you can control the B1500A from an external computer by using Keysight FLEX command set that is the common language for Keysight semiconductor DC measurement instruments. So you can reuse the measurement program created for Keysight 4155/4156/E5260/E5270.



- Keysight B1500A Semiconductor Device Analyzer

  Mainframe that provides the ground unit (GNDU) and ten empty slots for the measurement facilities, and Keysight EasyEXPERT software for the operating environment. The EasyEXPERT is the GUI based measurement control and analysis software runs on the Windows.

  This instrument is equipped with the 15 inch LCD with touch panel, hard disk drive, DVD drive, and USB/LAN/GP-IB interfaces. This instrument is also furnished the USB keyboard, the USB mouse, and the stylus pen.

- HRSMU module

  High resolution source/monitor unit module. Occupies one slot. Needs Keysight E5288A ASU to perform atto level current measurement or automatic switching of the measurement resource connected to the device under test (DUT).

- HPSMU module

  High power source/monitor unit module. Occupies two slots.

- MPSMU module

  Medium power source/monitor unit module. Occupies one slot. Needs Keysight E5288A ASU to perform atto level current measurement or automatic switching of the measurement resource connected to the device under test (DUT). ASU is effective for the B1511B MPSMU. ASU cannot be connected to the B1511A MPSMU.

- MCSMU module

  Medium current source/monitor unit module. Occupies one slot.

- MFCMU module

  Multi frequency capacitance measurement unit module. Occupies one slot. Needs Keysight N1301A-100 SCUU to perform automatic switching of the measurement resource connected to the DUT.

- SPGU module

  High voltage semiconductor pulse generator unit module. Occupies one slot. Up to five modules can be installed in one mainframe. One module provides two output channels. Needs Keysight 16440A (B1500A-A04) and 16445A to perform automatic switching of the measurement resource connected to the DUT.

- WGFMU module and RSU

  Waveform generator/fast measurement unit module and the remote-sense and switch unit. Occupies one slot. Up to five modules can be installed in one mainframe. One module provides two channels. See Keysight B1530A *User's Guide* for using the WGFMU.

- Keysight 16440A SMU/PGU pulse generator selector (B1500A-A04)

  Used to switch the measurement resource connected to the DUT. The measurement resource can be SPGU or SMU. Needs the 16445A adapter to use the selector. One selector provides two switching channels.

- Keysight 16442B test fixture (B1500A-A5F)

  Test fixture for semiconductor parameter analyzers and device analyzers. Provides three Kelvin triaxial connectors (six non-Kelvin triaxial connectors) for connecting SMU, six BNC connectors for connecting SPGU, MFCMU, or other instruments, a GNDU connector, and an Intlk connector. Furnished with the dual-in-line package socket module, universal socket modules (two types), blank PTFE board, and connection wires for device connection.

- Keysight 16445A selector adapter

  Used to connect the 16440A selector (B1500A-A04) to the B1500A. Two selectors can be connected.

- Keysight E5288A ASU

  Atto sense and switch unit (ASU). Used to enable the 1 pA range for the atto level current measurement, also switch the measurement resource connected to the DUT. The measurement resource can be HRSMU/MPSMU (B1511B) or the instrument connected to the AUX terminal.

- Keysight N1255A 2 channel connection box for MCSMU

  Connection box to make the MCSMU connection easy. Supports two MCSMU.

- Keysight N1301A-100 SCUU

  SMU CMU unify unit (SCUU). Used to switch the measurement resource connected to the DUT. The measurement resource can be CMU or one of two HRSMU/MPSMU connected to the SCUU.

- Keysight N1301A-200 GSWU

  Guard switch unit (GSWU). Needs the SCUU to use the GSWU. Effective for the accurate impedance measurements by connecting the guard lines between CMU high and low near the DUT.

Keysight EasyEXPERT Software

Keysight EasyEXPERT software is a specially-designed Windows application program for controlling Keysight B1500A. The EasyEXPERT provides the easy and effective measurement and analysis environment with intuitive graphical user interface (GUI), touch screen LCD panel, keyboard, and mouse. Some of the functions are listed below.

- Single measurement, repeat measurement, and append measurement
- Switching matrix control

  Supported models:

  - Keysight B2200A/B2201A switching matrix
  - Keysight E5250A switching matrix with E5252A
- Measurement/setup data management by workspace
- Graph display and analysis with markers, cursors, and lines; and auto analysis
- Data import/export capability, data output by CSV/XML format, and graph output by EMF/BMP/GIF/PNG format
- Maintenance; self-test and self-calibration
- Remote control function from an external computer

The EasyEXPERT has the following measurement execution environments.

- Application test
- Classic test
- Tracer test
- Quick test

Application Test

The EasyEXPERT contains an application library that supports typical measurements for CMOS devices, TFT, BJT, memory, nanotechnology devices such as CNT FET, and so on. The application library includes more than two hundred test definitions.

You can perform measurements by choosing the best one for your device under test (DUT) from the application libraries, and modifying and executing it. Modification is really simple. For example, it will be completed by changing the output voltage only to DUT terminals. And the setup with your modifications can be saved and recalled as your setup (*My Favorite Setup*).

Classic Test

You can perform measurements by using the user interface similar to the semiconductor parameter analyzers such as Keysight 4156C. The setup can be made by entering values into the setup tables used for the measurement module control. And it can be saved and recalled as your setup (*My Favorite Setup*). This measurement environment provides the following functions.

- I/V Sweep
- Multi Channel I/V Sweep
- I/V List Sweep
- I/V-t Sampling
- C-V Sweep
- SPGU Control
- Switching Matrix Control
- Direct Control

The Direct Control test mode is used to control the measurement modules directly by using the B1500A GPIB control commands and perform measurement. For the control commands, see “Programming Guide”.

Tracer Test

Curve tracer test mode. This test allows you to perform the high speed I-V measurement on one screen. The Tracer Test screen provides GUI for selecting the used channels, setting the sweep output, and displaying the measurement result (tracing the I-V curve). Range of the sweep output and measurement can be changed by the rotary knob on the front panel.

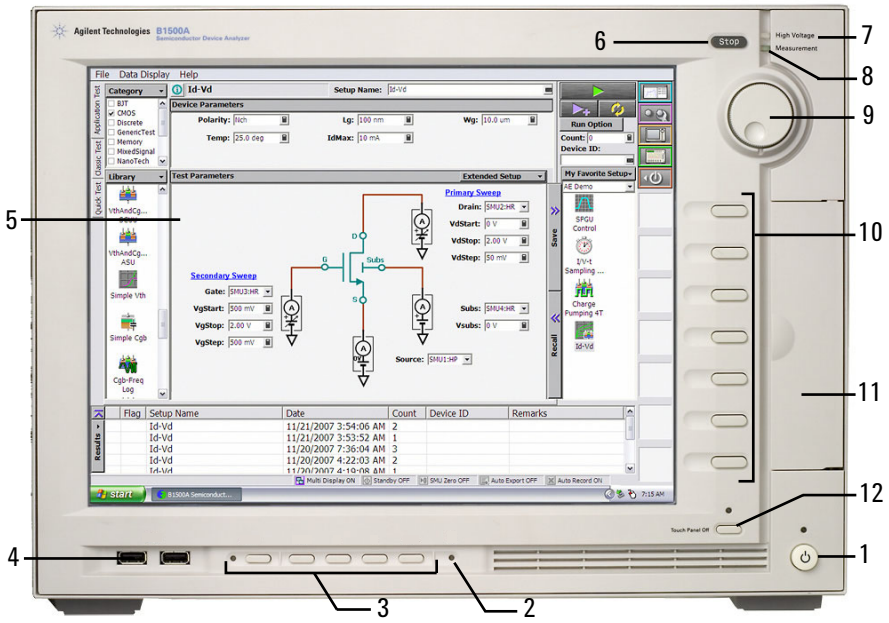
Tracer test also provides the oscilloscope view to display the pulse current or voltage output waveform of the MCSMU. You can verify output waveform over the I-V curve.

Quick Test

You can execute the test setups saved in a preset group (*My Favorite Setup*) sequentially.

Front View

This section describes the front view of Keysight B1500A.



1. Standby switch

   Turns the instrument on. Pressing the button in the ON state makes it in the standby state. The green LED lights when it is in the ON state.

NOTE

When turning the B1500A on

Open the measurement terminals at the device side when turning the B1500A on. Also disconnect the device from the measurement terminals and open the measurement terminals after the measurement. If you leave the connection with the device, the device may be damaged by unexpected operations or charge-up of measurement cables.

2. HDD access indicator

   This green LED lights in the access status of HDD or DVD drive. Do not turn the instrument off during this LED lights.

3. LCD adjustment keys

   LCD Off enables or disables the LCD panel. The green LED lights when the LCD is disabled.

   Four keys are available for adjusting brightness. Use + and - to adjust it and then press *Set* to fix it. Pressing *Cancel* instead of *Set* cancels the adjustment.

4. USB interfaces

   USB, 2 ports. For keyboard, mouse, and so on.

   To remove USB devices from the instrument, use “Safely Remove Hardware” on Windows taskbar. If it is not used, the instrument may cause the internal USB communication error. If the error occurs, turn the instrument off and disconnect the power cable from it. Leave it about 30 seconds before rebooting it, and connect the power cable again, and then turn the instrument on.

5. LCD panel

   15 inch TFT XGA display, 1024 × 768 resolution. Displays the Windows screen, Keysight EasyEXPERT software window, and so on. Touch screen operation is available when the Touch Panel Off indicator does not light.

   To adjust the touch panel, use Microchip TSHARC Control Panel which is opened by selecting *Microchip TSHARC Control Panel* from the Start menu.

6. Stop key

   Stops the present measurement or source output immediately.

7. High voltage status indicator

   This red LED lights when a source channel applies more than ± 42 V.

8. Measurement status indicator

   This green LED lights when a measurement channel performs measurement.

9. Rotary knob

   Works on Keysight EasyEXPERT environment. Rotating the knob moves the marker on the graph window, or increases/decreases/changes the value in the active entry field. Pressing the knob sets or enters the value.

10. Softkeys

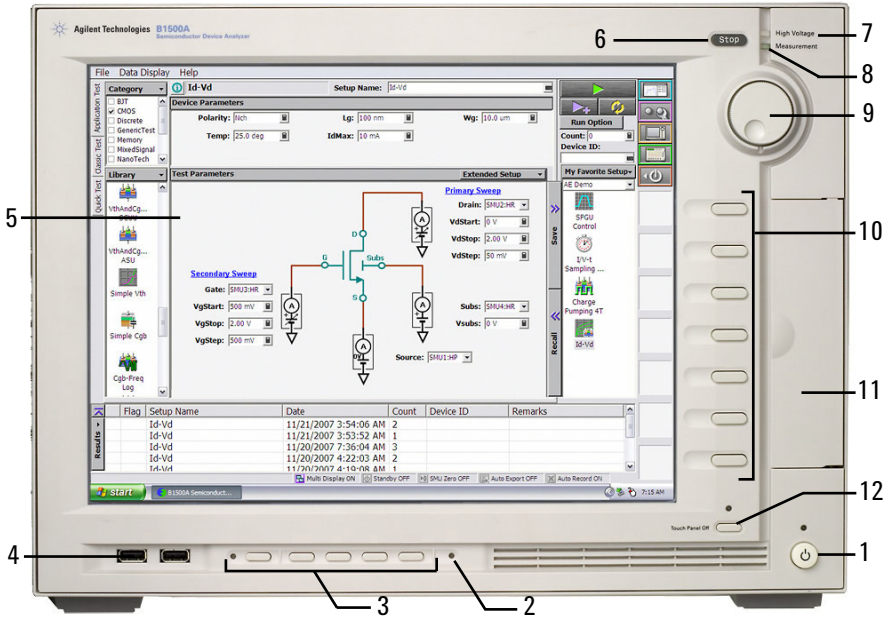
    Seven softkeys are available for Keysight EasyEXPERT environment. Used to select an alternative for the entry field specified or the dialog box.

11. DVD-R drive

    For data backup, software update, and so on. With the option DR1, the drive is changed to the DVD-ROM drive.

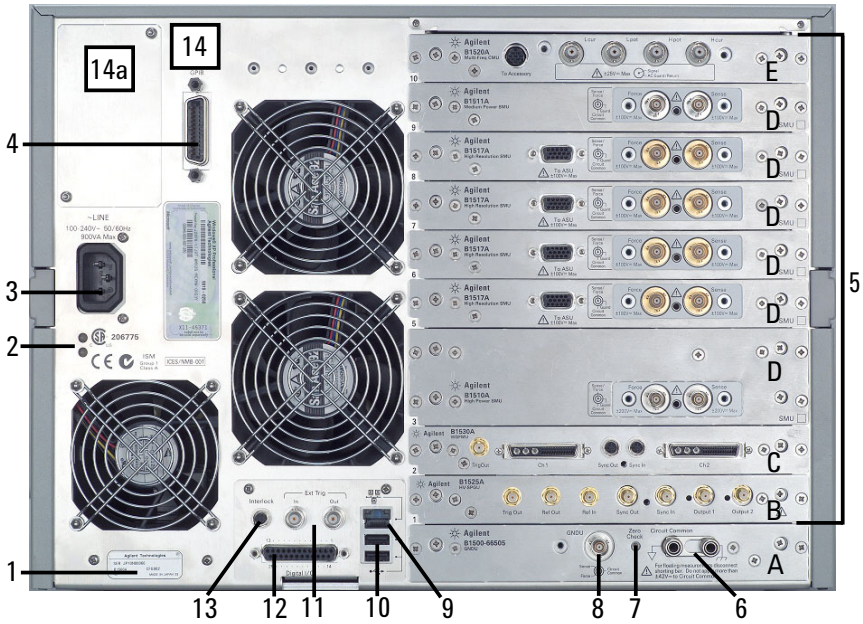
12. Touch Panel Off key

    Works on the execution environment of EasyEXPERT software. Enables or disables the touch screen operation. The green LED lights when the touch screen is disabled.



Rear View

This section describes the rear view of Keysight B1500A.



1. Serial number

   You need this *serial number* when using Keysight Technologies telephone assistance program.

2. LED status indicator

   For troubleshooting. Followings are some examples.

   - Both LEDs turn off:

     The instrument is in the standby state and Standby switch is OFF position.

   - One LED turns green:

     Power supply works normally.

   - Both LEDs turn orange:

     The instrument is in the standby state and Standby switch is ON position.

3. LINE input receptacle

   AC power cable is connected to this receptacle.

4. GPIB interface

   Use a Keysight 82357A USB/GPIB interface or Keysight 10833A/B/C/D GPIB cable to connect to an external computer or equipment.

5. Module slot

   Ten slots are available for installing the modules. Several kinds of module can be installed in the B1500A. However, the allowable number to install is different by the module type. See "Measurement Modules" on page 2-17. Also, there is a rule for the installation order by the module type. See Chapter 3, "Installation."

6. Circuit Common (⏚) and Frame ground (⏚) terminals

   Normally, connect the terminals together by using the shorting bar (Keysight part number 5000-4206). For floating measurement, remove the shorting bar.

WARNING **If the Circuit Common terminal is *not* connected to the frame ground terminal (for floating measurement), a potential shock hazard may present. Do not touch any of measurement circuit at any time while a floating measurement is in progress.**

CAUTION For floating measurement, do not apply dangerous voltage to the Circuit Common terminal. Failure to heed this caution may result in damage to the instrument.

7. Zero Check terminal

   Ground reference point of the instrument.

CAUTION The Zero Check terminal can be used for the service purpose only. For the normal operation, leave this terminal open and do not connect anything to this terminal. Connecting anything can damage the instrument.

8. GNDU terminal

   0 V constant voltage source. Used for the reference of measurement ground. Triaxial connector.

9. LAN interface

   RJ45 connector.

10. USB interfaces

    USB, 2 ports. For keyboard, mouse, or peripherals.

    To remove USB devices from the instrument, use “Safely Remove Hardware” on Windows taskbar. If it is not used, the instrument may cause the internal USB communication error. If the error occurs, turn the instrument off and disconnect the power cable from it. Leave it about 30 seconds before rebooting it, and connect the power cable again, and then turn the instrument on.

11. Ext Trig terminals

    Two BNC connectors, one for trigger input, and one for trigger output. For details about the trigger function, see *Programming Guide*.

12. Digital I/O terminal

    DSUB 25 pin connector. Can be used for the trigger input/output terminals or an interface to control an external relay circuit and so on. For details, see *Programming Guide*. This connector is also used to connect Keysight 16445A selector adapter.

⚠ 13. Interlock terminal

    Used in conjunction with the interlock function of the instrument. If the Interlock terminal is open, maximum SMU output is limited to ±42 V. Be sure to connect this terminal to the interlock circuit of the 16442B test fixture (B1500A-A5F) or the prober station before performing measurement. For the interlock circuit, see “To Make an Interlock Circuit” on page 3-31.

    To verify the interlock function, perform the Interlock Open/Close test on the Main Frame tab screen of the EasyEXPERT Configuration window.

WARNING **Dangerous voltage, instrument maximum output voltage may appear at Force, Guard, and Sense terminals if the Interlock terminal is closed.**

14. Video output terminal

    VGA connector. For an external display. Signal to the built-in LCD is also applied to this terminal.

    For the B1500A manufactured before the video output terminal is supported, it is mounted on the position “14a” by upgrading the mainframe.

A. GNDU/ADC

Ground unit and A/D converter module. Always installed in the B1500A.

B. SPGU module

The semiconductor pulse generator unit (SPGU) has the Output 1 and Output 2 terminals and the following terminals to synchronize the operation between SPGUs or with an external equipment.

Ref Out/Sync Out: Connect to the Ref In/Sync In of the slave SPGU.

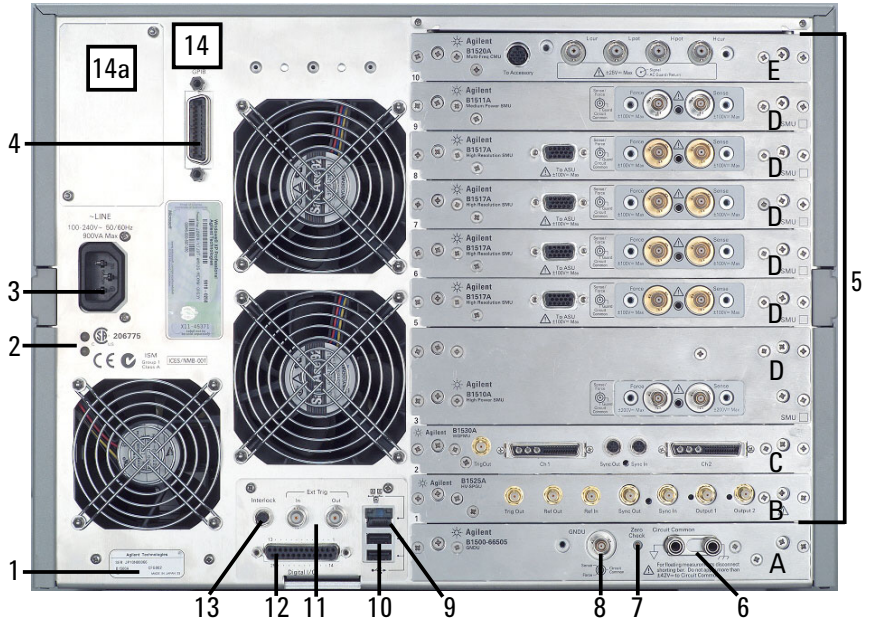
Ref In/Sync In: Connect to the Ref Out/Sync Out of the master SPGU.

Trig Out: Connect to the trigger input terminal of the equipment synchronized with the SPGU output.

CAUTION

Connect the Ref Out/In, Sync Out/In, and Trig Out terminals to the specified terminal properly. Connecting to the other terminal may result in damage to the SPGU.

In the EasyEXPERT operation mode, the SPGU outputs can be specified by the PG number. PG1 and PG2 are assigned to the Output 1 and Output 2 terminals of the SPGU at the lowest position. And the following PG numbers are assigned to the outputs of the upper SPGUs in sequence. Use the PG number label furnished with the B1500A or equivalent to identify the SPGU channel number.



C. WGFMU module

The waveform generator/fast measurement unit (WGFMU) has the Ch 1 and Ch 2 terminals and the following terminals to synchronize the operation between WGFMUs or with an external equipment.

Sync Out: Connect to the Sync In of the slave WGFMU.

Sync In: Connect to the Sync Out of the master WGFMU.

Trig Out: Connect to the trigger input terminal of the equipment synchronized with the WGFMU output.

CAUTION

Connect the Sync Out/In, and Trig Out terminals to the specified terminal properly. Connecting to the other terminal may result in damage to the WGFMU.

Connect the connection cable between the WGFMU and the RSU (remote-sense and switch unit) before turning the instrument on. Changing the cable connection in the power on state may damage them. See Keysight B1530A *User's Guide* for cable connection and usage.

D. SMU module

The source/monitor unit (SMU) has two triaxial connectors, force and sense, for the Kelvin connections.

The HRSMU (high resolution SMU) and MPSMU (B1511B medium power SMU) also have a D-sub connector (To ASU terminal) which is used to connect the ASU (atto sense and switch unit).

In the EasyEXPERT operation mode, the SMUs can be specified by the SMU number. SMU1 is assigned to the SMU at the lowest position. And the following SMU numbers are assigned to the upper SMUs in sequence. Use the SMU number label furnished with the B1500A or equivalent to identify the SMU number.

NOTE

Connect the connection cables between the SMU and the ASU before turning the instrument on. Changing the cable connection in the power on state may damage them. To connect the ASU, see "To Connect ASU" on page 3-17.

E. CMU module

The multi frequency capacitance measurement unit (MFCMU) has four coaxial connectors, Lcur, Lpot, Hpot, and Hcur, for the four-terminal pair connection. The Hcur and Hpot have to be connected together at a terminal of the device

under test (DUT). Also the Lcur and Lpot have to be connected together at the other terminal of the DUT. Then, the guard lines of four-terminal pair must be connected together.

CAUTION Do not apply voltage more than ±25 V to the MFCMU input terminals. Failure to heed this caution may result in damage to the module.

WARNING **To avoid electrical shock and instrument damage, turn the all instruments off before connecting or disconnecting measurement cable.**

WARNING ⚠ **There are potentially hazardous voltages (± 200 V for HPSMU, and ± 100 V for MPSMU/HRSMU) present at the Force, Sense, and Guard terminals of this instrument. To prevent electrical shock, the following safety precautions must be observed during the use of the instrument.**

- **Use a three-conductor AC power cable to connect the instrument to an electrical ground (safety ground).**
- **If you do *not* use the B1500A-A5F/16442A/B test fixture, you must install and connect an interlock circuit that opens the Interlock terminal when the shielding box access door is opened.**
- **If you change the DUT interface, test fixture, prober, and such, connect an interlock cable to the one actually used.**
- **Confirm periodically that the interlock function works normally.**
- **Before touching the connections on the Force, Guard, and Sense terminals in the test fixture or the shielding box, turn the instrument off and discharge any capacitors. If you do *not* turn the instrument off, complete *all* of the following items, regardless of the instrument settings.**
  - **Press the front panel Stop key to set the module output off.**
  - **Confirm that the front panel High Voltage indicator is not lit.**
  - **Open the Interlock terminal (open the fixture cover or the shielding box access door).**
  - **Discharge any capacitors connected to a measurement resource.**
- **Warn persons working around the instrument about dangerous conditions.**

Measurement Modules

Keysight B1500A can be equipped with the following measurement modules.

- "GNDU - Ground Unit"
- "HPSMU - High Power SMU"
- "MPSMU - Medium Power SMU"
- "MCSMU - Medium Current SMU"
- "HRSMU - High Resolution SMU"
- "MFCMU - Multi Frequency CMU"
- "HVSPGU - High Voltage SPGU"
- "WGFMU - Waveform Generator/Fast Measurement Unit"

See Keysight EasyEXPERT *User's Guide* for the functions available for Keysight EasyEXPERT software. See *Programming Guide* for the functions available for the GPIB remote mode. See Keysight B1530A *User's Guide* for using the WGFMU.

GNDU - Ground Unit

Keysight B1500A is equipped with the ground unit (GNDU). The GNDU is a 0 V constant voltage source, and used for the reference of measurement ground. Also the GNDU can sink up to ± 4.2 A, so it is effective for using the HPSMU (high power SMU). Figure 2-1 is a simplified circuit diagram of GNDU.

Figure 2-1 Simplified GNDU Circuit Diagram

About SMU

Source/monitor unit (SMU) can apply DC voltage or current, and can measure DC current or voltage. Figure 2-2 is a simplified SMU circuit diagram. The SMU can perform the following operations:

The HPSMU, MPSMU, and HRSMU can perform the following operations:

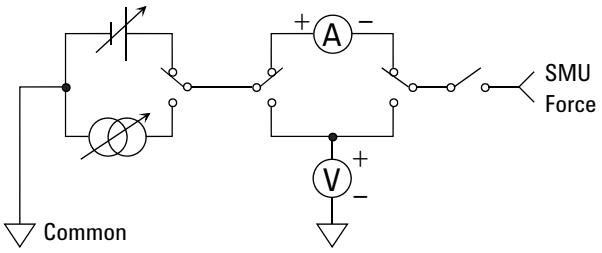
- Apply voltage and measures current or voltage
- Apply current and measures current or voltage

The MCSMU can perform the following operations:

- Apply voltage and measures current and/or voltage
- Apply current and measures current and/or voltage

NOTE To select the SMU operation mode in the GPIB remote condition, enter the CMM command.

Figure 2-2 Simplified SMU Circuit Diagram



Compliance

The SMU has a compliance feature that limits output voltage or current to prevent damage to the device under test. When the SMU applies voltage, you can specify current compliance. When the SMU applies current, you can specify voltage compliance. For details about the compliance, see Keysight EasyEXPERT *User's Guide*.

HPSMU - High Power SMU

This section describes typical specification of the high power source/monitor unit (HPSMU). Maximum four modules can be installed in one mainframe.

- Maximum voltage, current, output power: ± 200 V, ± 1 A, 20 W
- Minimum range: 2 V, 1 nA
- Output/measurement value and resolution: see Table 2-1 to Table 2-4.

Figure 2-3 HPSMU Output and Measurement Ranges

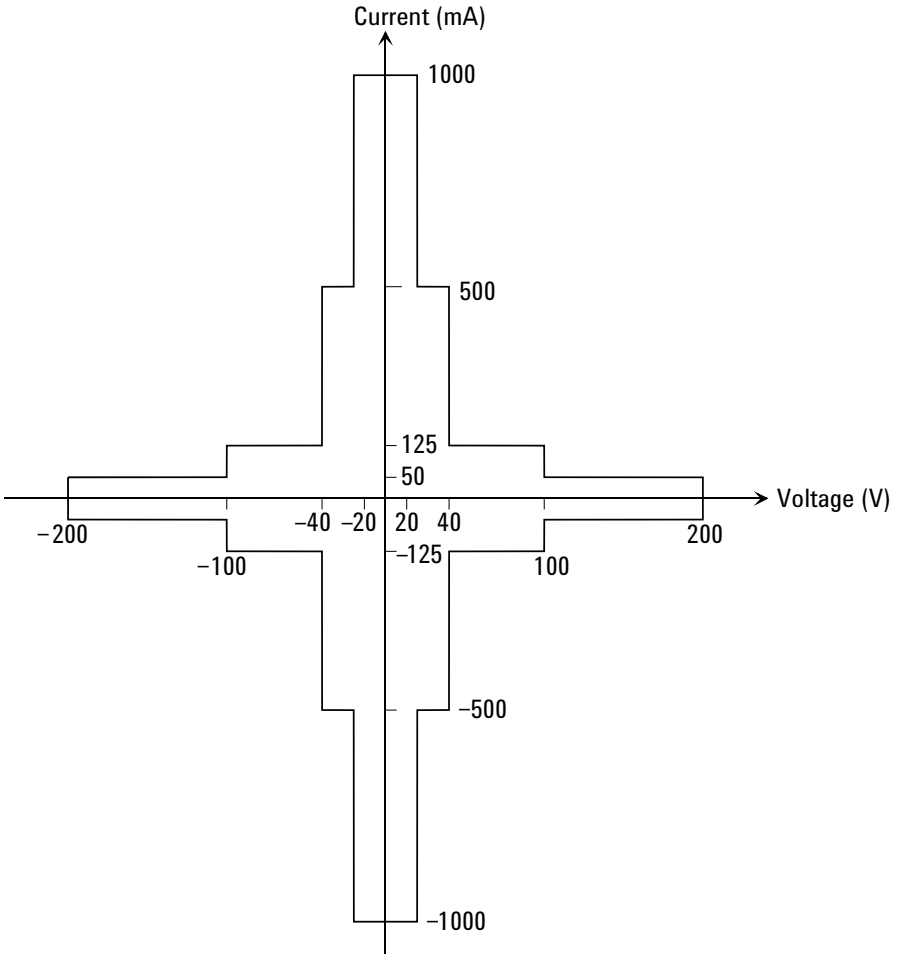


Table 2-1 HPSMU Output Voltage Ranges and Resolutions

Range	Output Value	Setting Resolution	Maximum Current
2 V	0 ≤ |V| ≤ 2 V	100 µV	± 1000 mA
20 V	0 ≤ |V| ≤ 20 V	1 mV	± 1000 mA
40 V	0 ≤ |V| ≤ 40 V	2 mV	± 500 mA
100 V	0 ≤ |V| ≤ 100 V	5 mV	± 125 mA
200 V	0 ≤ |V| ≤ 200 V	10 mV	± 50 mA

Table 2-2 HPSMU Output Current Ranges and Resolutions

Range	Output Value	Setting Resolution	Maximum Voltage
1 nA	0 ≤ |I| ≤ 1.15 nA	50 fA	± 200 V
10 nA	0 ≤ |I| ≤ 11.5 nA	500 fA	± 200 V
100 nA	0 ≤ |I| ≤ 115 nA	5 pA	± 200 V
1 µA	0 ≤ |I| ≤ 1.15 µA	50 pA	± 200 V
10 µA	0 ≤ |I| ≤ 11.5 µA	500 pA	± 200 V
100 µA	0 ≤ |I| ≤ 115 µA	5 nA	± 200 V
1 mA	0 ≤ |I| ≤ 1.15 mA	50 nA	± 200 V
10 mA	0 ≤ |I| ≤ 11.5 mA	500 nA	± 200 V
100 mA	0 ≤ |I| ≤ 50 mA	5 µA	± 200 V
	50 mA < |I| ≤ 115 mA	5 µA	± 100 V
1 A	0 ≤ |I| ≤ 50 mA	50 µA	± 200 V
	50 mA < |I| ≤ 125 mA	50 µA	± 100 V
	125 mA < |I| ≤ 500 mA	50 µA	± 40 V
	500 mA < |I| ≤ 1 A	50 µA	± 20 V

Table 2-3 HPSMU Measurement Voltage Values and Resolutions

Range	Measurement Value [a]	Measurement Resolutions	
		High Speed ADC	High Resolution ADC
2 V	0 ≤ |V| ≤ 2.2 V	100 μV	2 μV
20 V	0 ≤ |V| ≤ 22 V	1 mV	20 μV
40 V	0 ≤ |V| ≤ 44 V	2 mV	40 μV
100 V	0 ≤ |V| ≤ 110 V	5 mV	100 μV
200 V	0 ≤ |V| ≤ 200 V	10 mV	200 μV

Table 2-4 HPSMU Measurement Current Values and Resolutions

Range	Measurement Value [a]	Measurement Resolutions	
		High Speed ADC	High Resolution ADC
1 nA	0 ≤ |I| ≤ 1.15 nA	50 fA	10 fA
10 nA	0 ≤ |I| ≤ 11.5 nA	500 fA	10 fA
100 nA	0 ≤ |I| ≤ 115 nA	5 pA	100 fA
1 μA	0 ≤ |I| ≤ 1.15 μA	50 pA	1 pA
10 μA	0 ≤ |I| ≤ 11.5 μA	500 pA	10 pA
100 μA	0 ≤ |I| ≤ 115 μA	5 nA	100 pA
1 mA	0 ≤ |I| ≤ 1.15 mA	50 nA	1 nA
10 mA	0 ≤ |I| ≤ 11.5 mA	500 nA	10 nA
100 mA	0 ≤ |I| ≤ 115 mA	5 μA	100 nA
1 A	0 ≤ |I| ≤ 1 A	50 μA	1 μA

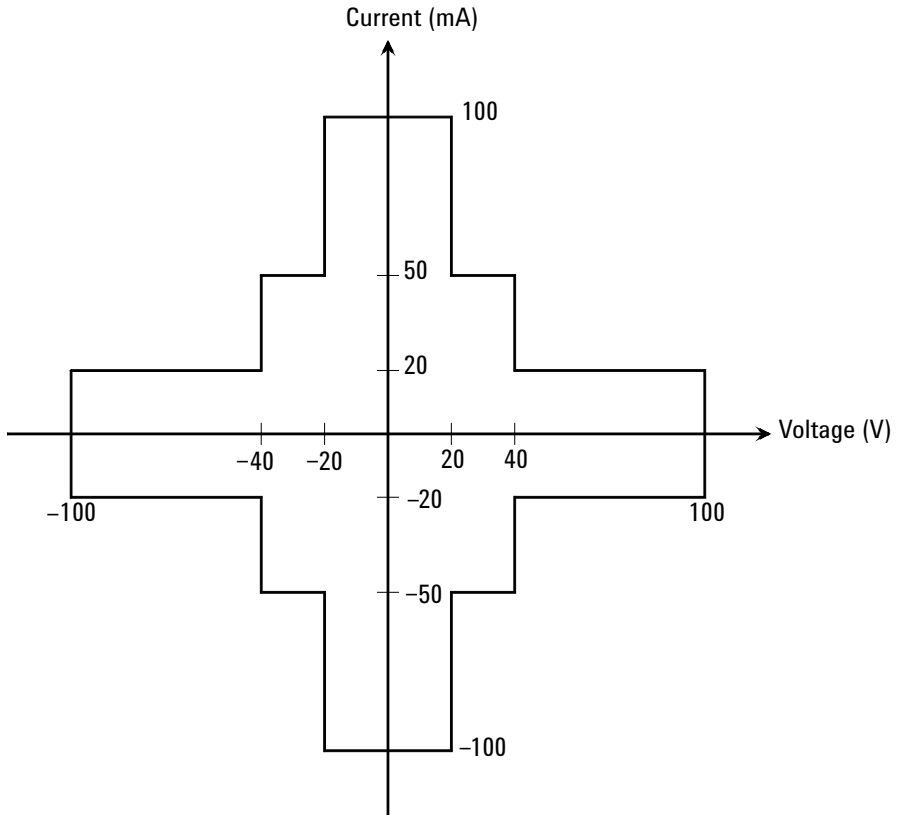
a. This column is applied to the auto ranging or the limited auto ranging. For fixed ranging, maximum measurement value is **Range** column value.

MPSMU - Medium Power SMU

This section describes typical specification of the medium power source/monitor unit (MPSMU). There is no restriction for the number of modules installed in one mainframe.

- Maximum voltage, current, output power: ± 100 V, ± 100 mA, 2 W
- Minimum range: 0.5 V, 1 nA (1 pA when the E5288A ASU is used)
- Output/measurement value and resolution: see Table 2-5 to Table 2-8.

Figure 2-4 **MPSMU Output and Measurement Ranges**



NOTE The E5288A Atto Sense and Switch Unit (ASU) can be connected to the B1511B MPSMU, but it cannot be connected to the B1511A MPSMU.

Table 2-5 MPSMU Output Voltage Ranges and Resolutions

Range	Output Value	Setting Resolution	Maximum Current
0.5 V	0 ≤ |V| ≤ 0.5 V	25 µV	± 100 mA
2 V	0 ≤ |V| ≤ 2 V	100 µV	± 100 mA
5 V	0 ≤ |V| ≤ 5 V	250 µV	± 100 mA
20 V	0 ≤ |V| ≤ 20 V	1 mV	± 100 mA
40 V	0 ≤ |V| ≤ 20 V	2 mV	± 100 mA
	20 V < |V| ≤ 40 V	2 mV	± 50 mA
100 V	0 ≤ |V| ≤ 20 V	5 mV	± 100 mA
	20 V < |V| ≤ 40 V	5 mV	± 50 mA
	40 V < |V| ≤ 100 V	5 mV	± 20 mA

Table 2-6 MPSMU Output Current Ranges and Resolutions

Range	Output Value	Setting Resolution	Maximum Voltage
1 pA [a]	0 ≤ |I| ≤ 1.15 pA	1 fA	± 100 V
10 pA [a]	0 ≤ |I| ≤ 11.5 pA	5 fA	± 100 V
100 pA [a]	0 ≤ |I| ≤ 115 pA	5 fA	± 100 V
1 nA	0 ≤ |I| ≤ 1.15 nA	50 fA	± 100 V
10 nA	0 ≤ |I| ≤ 11.5 nA	500 fA	± 100 V
100 nA	0 ≤ |I| ≤ 115 nA	5 pA	± 100 V
1 µA	0 ≤ |I| ≤ 1.15 µA	50 pA	± 100 V
10 µA	0 ≤ |I| ≤ 11.5 µA	500 pA	± 100 V
100 µA	0 ≤ |I| ≤ 115 µA	5 nA	± 100 V
1 mA	0 ≤ |I| ≤ 1.15 mA	50 nA	± 100 V
10 mA	0 ≤ |I| ≤ 11.5 mA	500 nA	± 100 V
100 mA	0 ≤ |I| ≤ 20 mA	5 µA	± 100 V
	20 mA < |I| ≤ 50 mA	5 µA	± 40 V
	50 mA < |I| ≤ 100 mA	5 µA	± 20 V

a. For B1511B MPSMU. Available when the ASU is used.

Table 2-7 **MPSMU Measurement Voltage Values and Resolutions**

Range	Measurement Value [a]	Measurement Resolutions	
		High Speed ADC	High Resolution ADC
0.5 V	0 ≤ |V| ≤ 0.55 V	25 μV	0.5 μV
2 V	0 ≤ |V| ≤ 2.2 V	100 μV	2 μV
5 V	0 ≤ |V| ≤ 5.5 V	250 μV	5 μV
20 V	0 ≤ |V| ≤ 22 V	1 mV	20 μV
40 V	0 ≤ |V| ≤ 44 V	2 mV	40 μV
100 V	0 ≤ |V| ≤ 100 V	5 mV	100 μV

Table 2-8 **MPSMU Measurement Current Values and Resolutions**

Range	Measurement Value [a]	Measurement Resolutions	
		High Speed ADC	High Resolution ADC
1 pA [b]	0 ≤ |I| ≤ 1.15 pA	100 aA	100 aA
10 pA [b]	0 ≤ |I| ≤ 11.5 pA	1 fA	400 aA
100 pA [b]	0 ≤ |I| ≤ 115 pA	5 fA	500 aA
1 nA	0 ≤ |I| ≤ 1.15 nA	50 fA	10 fA
10 nA	0 ≤ |I| ≤ 11.5 nA	500 fA	10 fA
100 nA	0 ≤ |I| ≤ 115 nA	5 pA	100 fA
1 μA	0 ≤ |I| ≤ 1.15 μA	50 pA	1 pA
10 μA	0 ≤ |I| ≤ 11.5 μA	500 pA	10 pA
100 μA	0 ≤ |I| ≤ 115 μA	5 nA	100 pA
1 mA	0 ≤ |I| ≤ 1.15 mA	50 nA	1 nA
10 mA	0 ≤ |I| ≤ 11.5 mA	500 nA	10 nA
100 mA	0 ≤ |I| ≤ 100 mA	5 μA	100 nA

a. This column is applied to the auto ranging or the limited auto ranging. For fixed ranging, maximum measurement value is **Range** column value.
b. For B1511B MPSMU. Available when the ASU is used.

NOTE

To connect ASU

To use the ASU, it must be connected to the SMU which is connected together when the calibration is performed. The specifications are satisfied and guaranteed in this condition only. So confirm the serial number of the ASU and connect it to the dedicated SMU properly.

To connect the ASU, see "To Connect ASU" on page 3-17.

To confirm the serial number, see Keysight EasyEXPERT *User's Guide*.

NOTE

Before using 1 pA range

The measurement channel connected to the ASU supports the 1 pA range. To use the 1 pA range, set the 1 pA fixed range or the 1 pA limited auto ranging.

The B1500A automatically performs the compensation of the data measured by the 1 pA range and returns the compensated data. You can use either the pre-stored offset data or the pre-measured offset data.

To measure the offset data, perform the self-calibration before starting the measurement for a DUT. This offset data is temporarily memorized until the B1500A is turned off.

MCSMU - Medium Current SMU

This section describes typical specification of the medium current source/monitor unit (MCSMU). Maximum four modules can be installed in one mainframe.

- Maximum current: ± 1 A (pulse), ± 0.1 A (DC)
- Maximum voltage: ± 30 V
- Maximum output power: 30 W (pulse), 3 W (DC)
- Minimum range: 0.2 V, 10 μA
- Minimum pulse width: 10 μs
- Output/measurement value and resolution: see Table 2-9 and Table 2-10.

Figure 2-5 **MCSMU Output and Measurement Ranges**

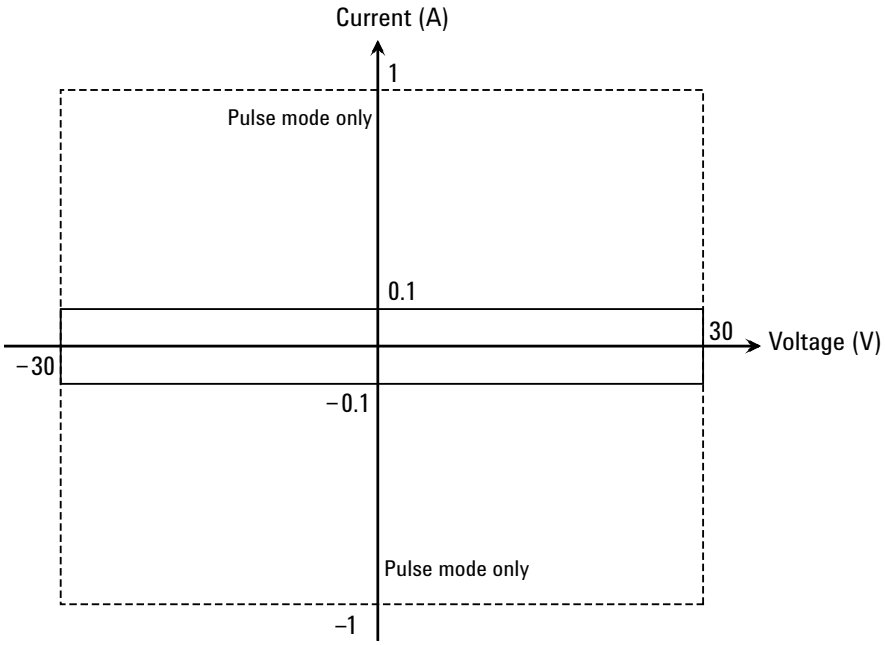


Table 2-9 MCSMU Voltage Ranges and Resolutions

Range	Output Value and Measurement Value	Setting/ Measurement Resolution	Maximum Current	Maximum Pulse Base Value
0.2 V	0 ≤ |V| ≤ 0.2 V	200 nV	100 mA, 1 A [a]	± 0.2 V
2 V	0 ≤ |V| ≤ 2 V	2 μV		± 2 V
20 V	0 ≤ |V| ≤ 20 V	20 μV		± 20 V
40 V	0 ≤ |V| ≤ 30 V	40 μV		± 30 V

a. For pulse.

Table 2-10 MCSMU Current Ranges and Resolutions

Range	Output Value and Measurement Value	Setting/ Measurement Resolution	Maximum Voltage	Maximum Pulse Base Value
10 μA	0 ≤ |I| ≤ 11.5 μA	10 pA	± 30 V	± 10 μA
100 μA	0 ≤ |I| ≤ 115 μA	100 pA		± 100 μA
1 mA	0 ≤ |I| ≤ 1.15 mA	1 nA		± 1 mA
10 mA	0 ≤ |I| ≤ 11.5 mA	10 nA		± 10 mA
100 mA	0 ≤ |I| ≤ 100 mA, 0 ≤ |I| ≤ 115 mA [a]	100 nA		± 100 mA
1 A [b]	0 ≤ |I| ≤ 1 A	1 μA		± 50 mA

a. For pulse.
b. For pulse. Maximum pulse width and duty cycle are 100 ms and 5 % respectively.

HRSMU - High Resolution SMU

This section describes typical specification of the high resolution source/monitor unit (HRSMU). There is no restriction for the number of modules installed in one mainframe.

- Maximum voltage, current, output power: ± 100 V, ± 100 mA, 2 W
- Minimum range: 0.5 V, 10 pA (1 pA when the E5288A ASU is used)
- Output/measurement value and resolution: see Table 2-11 to Table 2-14.

Figure 2-6 **HRSMU Output and Measurement Ranges**

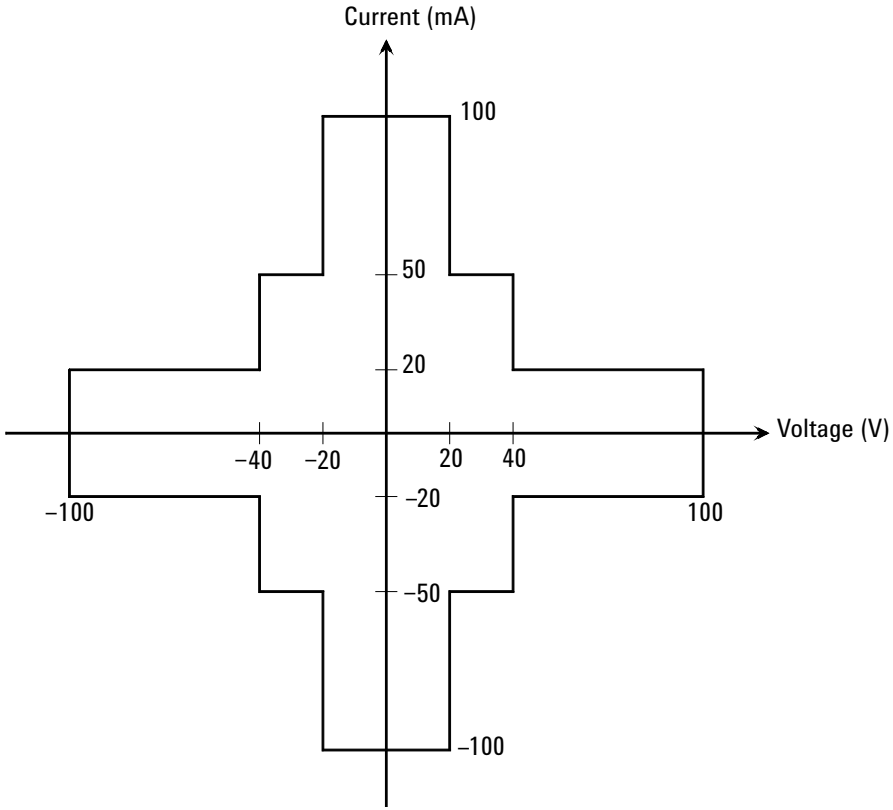


Table 2-11 HRSMU Output Voltage Ranges and Resolutions

Range	Output Value	Setting Resolution	Maximum Current
0.5 V	0 ≤ |V| ≤ 0.5 V	25 µV	± 100 mA
2 V	0 ≤ |V| ≤ 2 V	100 µV	± 100 mA
5 V	0 ≤ |V| ≤ 5 V	250 µV	± 100 mA
20 V	0 ≤ |V| ≤ 20 V	1 mV	± 100 mA
40 V	0 ≤ |V| ≤ 20 V	2 mV	± 100 mA
	20 V < |V| ≤ 40 V	2 mV	± 50 mA
100 V	0 ≤ |V| ≤ 20 V	5 mV	± 100 mA
	20 V < |V| ≤ 40 V	5 mV	± 50 mA
	40 V < |V| ≤ 100 V	5 mV	± 20 mA

Table 2-12 HRSMU Output Current Ranges and Resolutions

Range	Output Value	Setting Resolution	Maximum Voltage
1 pA [a]	0 ≤ |I| ≤ 1.15 pA	1 fA	± 100 V
10 pA	0 ≤ |I| ≤ 11.5 pA	5 fA	± 100 V
100 pA	0 ≤ |I| ≤ 115 pA	5 fA	± 100 V
1 nA	0 ≤ |I| ≤ 1.15 nA	50 fA	± 100 V
10 nA	0 ≤ |I| ≤ 11.5 nA	500 fA	± 100 V
100 nA	0 ≤ |I| ≤ 115 nA	5 pA	± 100 V
1 µA	0 ≤ |I| ≤ 1.15 µA	50 pA	± 100 V
10 µA	0 ≤ |I| ≤ 11.5 µA	500 pA	± 100 V
100 µA	0 ≤ |I| ≤ 115 µA	5 nA	± 100 V
1 mA	0 ≤ |I| ≤ 1.15 mA	50 nA	± 100 V
10 mA	0 ≤ |I| ≤ 11.5 mA	500 nA	± 100 V
100 mA	0 ≤ |I| ≤ 20 mA	5 µA	± 100 V
	20 mA < |I| ≤ 50 mA	5 µA	± 40 V
	50 mA < |I| ≤ 100 mA	5 µA	± 20 V

a. Available when the ASU is used.

Table 2-13 **HRSMU Measurement Voltage Values and Resolutions**

Range	Measurement Value [a]	Measurement Resolutions	
		High Speed ADC	High Resolution ADC
0.5 V	0 ≤ |V| ≤ 0.55 V	25 μV	0.5 μV
2 V	0 ≤ |V| ≤ 2.2 V	100 μV	2 μV
5 V	0 ≤ |V| ≤ 5.5 V	250 μV	5 μV
20 V	0 ≤ |V| ≤ 22 V	1 mV	20 μV
40 V	0 ≤ |V| ≤ 44 V	2 mV	40 μV
100 V	0 ≤ |V| ≤ 100 V	5 mV	100 μV

Table 2-14 **HRSMU Measurement Current Values and Resolutions**

Range	Measurement Value [a]	Measurement Resolutions	
		High Speed ADC	High Resolution ADC
1 pA [b]	0 ≤ |I| ≤ 1.15 pA	100 aA	100 aA
10 pA	0 ≤ |I| ≤ 11.5 pA	1 fA	1 fA / 400 aA [b]
100 pA	0 ≤ |I| ≤ 115 pA	5 fA	2 fA / 500 aA [b]
1 nA	0 ≤ |I| ≤ 1.15 nA	50 fA	10 fA
10 nA	0 ≤ |I| ≤ 11.5 nA	500 fA	10 fA
100 nA	0 ≤ |I| ≤ 115 nA	5 pA	100 fA
1 μA	0 ≤ |I| ≤ 1.15 μA	50 pA	1 pA
10 μA	0 ≤ |I| ≤ 11.5 μA	500 pA	10 pA
100 μA	0 ≤ |I| ≤ 115 μA	5 nA	100 pA
1 mA	0 ≤ |I| ≤ 1.15 mA	50 nA	1 nA
10 mA	0 ≤ |I| ≤ 11.5 mA	500 nA	10 nA
100 mA	0 ≤ |I| ≤ 100 mA	5 μA	100 nA

a. This column is applied to the auto ranging or the limited auto ranging. For fixed ranging, maximum measurement value is **Range** column value.
b. Available when the ASU is used.

NOTE

To connect ASU

To use the ASU, it must be connected to the SMU which is connected together when the calibration is performed. The specifications are satisfied and guaranteed in this condition only. So confirm the serial number of the ASU and connect it to the dedicated SMU properly.

To connect the ASU, see "To Connect ASU" on page 3-17.

To confirm the serial number, see Keysight EasyEXPERT *User's Guide*.

NOTE

Before using 1 pA range

The measurement channel connected to the ASU supports the 1 pA range. To use the 1 pA range, set the 1 pA fixed range or the 1 pA limited auto ranging.

The B1500A automatically performs the compensation of the data measured by the 1 pA range and returns the compensated data. You can use either the pre-stored offset data or the pre-measured offset data.

To measure the offset data, perform the self-calibration before starting the measurement for a DUT. This offset data is temporarily memorized until the B1500A is turned off.

MFCMU - Multi Frequency CMU

This section describes typical specification of the multi frequency capacitance measurement unit (CMU). The CMU performs the impedance measurement and returns the specified measurement data such as Cp-G. Only one module can be installed in one mainframe.

- Measurement parameters: See Table 2-15.
- AC signal, output frequency:

  1 kHz to 5 MHz

  Setting resolution: 1 mHz (1 kHz to), 10 mHz (10 kHz to), 0.1 Hz (100 kHz to), or 1 Hz (1 MHz to 5 MHz)
- AC signal, output level:

  10 mVrms to 250 mVrms, 1 mV resolution
- DC bias:

  0 to ± 25 V, using MFCMU internal DC bias

  0 to ± 100 V, using SMU and SCUU (SMU CMU unify unit)
- Measurement range:

  For the fixed ranging mode, measurement range (impedance range) must be specified to perform measurement. Table 2-16 shows the available measurement ranges and the corresponding impedance value. And Figure 2-7 shows the calculation example of the impedance vs frequency characteristics of a capacitive load. Use these information to decide the measurement range.

  Impedance Z is calculated by the following formula.

  $Z = 1 / (2\pi f C)$

  where f is frequency (Hz) and C is capacitance (F).

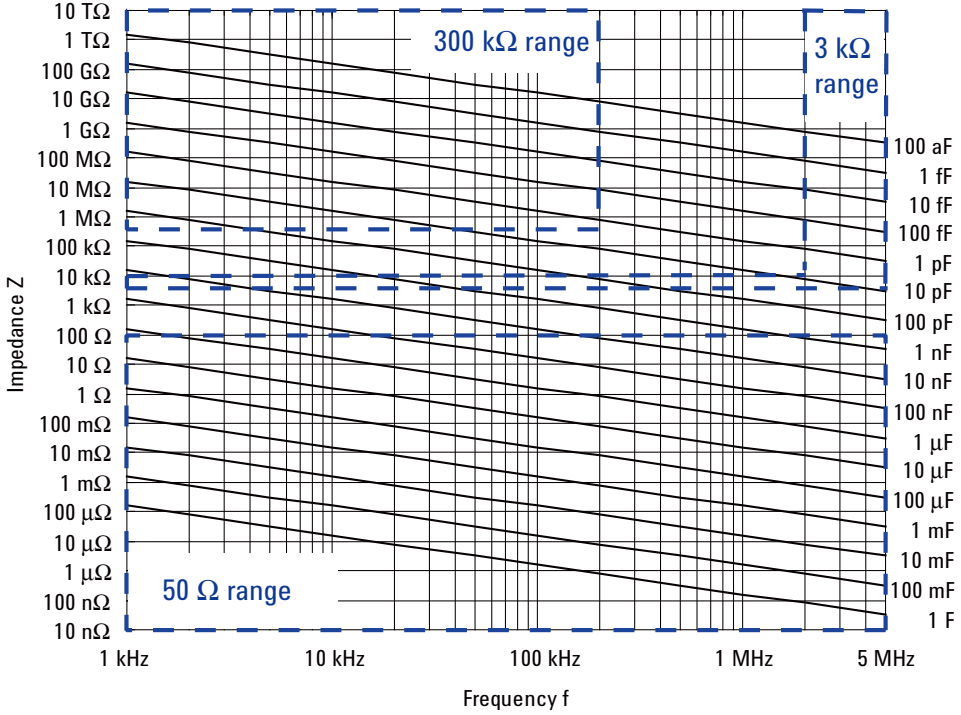
Table 2-15 Measurement Parameters

Primary Parameter	Secondary Parameter
R (resistance, Ω)	X (reactance, Ω)
G (conductance, S)	B (susceptance, S)
Z (impedance, Ω)	θ (phase, radian)
Z (impedance, Ω)	θ (phase, degree)
Y (admittance, S)	θ (phase, radian)
Y (admittance, S)	θ (phase, degree)
Cp (parallel capacitance, F)	G (conductance, S)
Cp (parallel capacitance, F)	D (dissipation factor)
Cp (parallel capacitance, F)	Q (quality factor)
Cp (parallel capacitance, F)	Rp (parallel resistance, Ω)
Cs (series capacitance, F)	Rs (series resistance, Ω)
Cs (series capacitance, F)	D (dissipation factor)
Cs (series capacitance, F)	Q (quality factor)
Lp (parallel inductance, H)	G (conductance, S)
Lp (parallel inductance, H)	D (dissipation factor)
Lp (parallel inductance, H)	Q (quality factor)
Lp (parallel inductance, H)	Rp (parallel resistance, Ω)
Ls (series inductance, H)	Rs (series resistance, Ω)
Ls (series inductance, H)	D (dissipation factor)
Ls (series inductance, H)	Q (quality factor)

Table 2-16 Measurement Range for Fixed Ranging Mode

Impedance Z	Measurement range (impedance range)		
	1 kHz ≤ f ≤ 200 kHz	200 kHz < f ≤ 2 MHz	2 MHz < f ≤ 5 MHz
0 ≤ Z < 100 Ω	50 Ω	50 Ω	50 Ω
100 Ω ≤ Z < 300 Ω	100 Ω	100 Ω	100 Ω
300 Ω ≤ Z < 1 kΩ	300 Ω	300 Ω	300 Ω
1 kΩ ≤ Z < 3 kΩ	1 kΩ	1 kΩ	1 kΩ
3 kΩ ≤ Z < 10 kΩ	3 kΩ	3 kΩ	3 kΩ
10 kΩ ≤ Z < 30 kΩ	10 kΩ	10 kΩ	
30 kΩ ≤ Z < 100 kΩ	30 kΩ	30 kΩ	
100 kΩ ≤ Z < 300 kΩ	100 kΩ		
300 kΩ ≤ Z	300 kΩ		

Figure 2-7 Impedance vs Frequency Characteristics of Capacitive Load, Calculation Example



HVSPGU - High Voltage SPGU

This section describes key specification of the high voltage semiconductor pulse generator unit (SPGU). Maximum five modules can be installed in one mainframe.

- Number of output channels: 2 channels per module
- Output impedance: 50 Ω
- Output level: 0 to ± 40 V (open load), ± 20 V (50 Ω load), 1 mV resolution
- SPGU operation mode:

  PG (pulse generator) or ALWG (arbitrary linear waveform generator)
- Channel output operation mode:

  Free run, duration, or pulse count (PG mode)/sequence count (ALWG mode)
- PG output mode:

  2-level pulse or 3-level pulse, for each channel
- Pulse timing parameters: (programmable range)

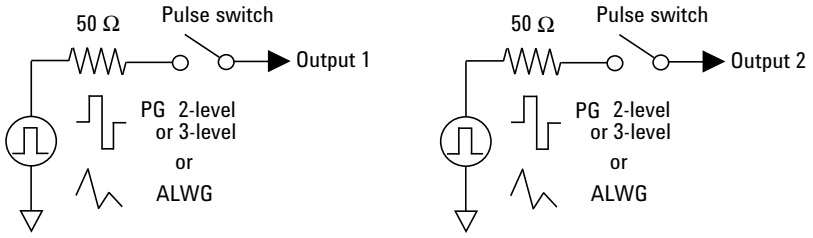
  Period: 20 ns to 10 s, 10 ns resolution

  Width: 10 ns to period - 10 ns, resolution 2.5 ns or 10 ns (transition time > 8 μs)

  Delay: 0 to period - 20 ns, resolution 2.5 ns or 10 ns (transition time > 8 μs)

  Transition time (leading time or trailing time): 8 ns to 400 ms, resolution 2 ns or 8 ns (transition time > 8 ms)
- Pulse switch, which is more durable than mechanical relays, and better suited for frequent switching applications.
- Automatic voltage level adjustment by specifying load impedance of DUT

Figure 2-8 **SPGU Simplified Circuit Diagram**



WGFMU - Waveform Generator/Fast Measurement Unit

This section describes typical specification of the waveform generator/fast measurement unit (WGFMU) and the remote-sense and switch unit (RSU). Maximum five modules can be installed in one mainframe.

- Number of channels: 2 channels per module
- Function:

  Voltage output and current or voltage sampling measurement with minimum sampling interval of 5 ns
- Current measurement range: 1 μA, 10 μA, 100 μA, 1 mA, or 10 mA
- Operation mode: PG mode, Fast IV mode, or DC mode
- PG mode:

  ALWG (arbitrary linear waveform generator) voltage output and voltage measurement (VFVM).

  Output level: -5 V to 5 V for open load or -2.5 V to 2.5 V for 50 Ω load

  Minimum pulse width: 50 ns
- Fast IV mode:

  ALWG voltage output and current or voltage measurement (VFIM or VFVM).

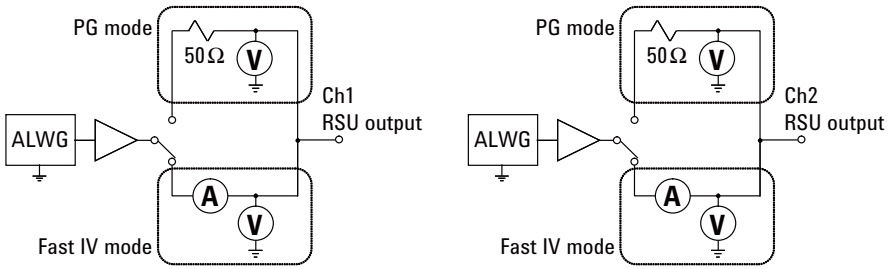
  Output level: 0 to -10 V, 0 to 10 V, or -5 V to 5 V

  Minimum pulse width (VFVM): 130 ns for 10 V output, 105 ns for 5 V output
- DC mode:

  DC voltage output and current or voltage measurement (VFIM or VFVM).

  Output level: 0 to -10 V, 0 to 10 V, or -5 V to 5 V

Figure 2-9 **WGFMU Simplified Circuit Diagram**



3 Installation

KEYSIGHT TECHNOLOGIES

This chapter describes how to install Keysight B1500A and accessories.

- "Requirements"
- "Inspection and Installation"
- "Installing Accessories"
- "Mounting Connectors"
- "Connecting Measurement Devices"
- "Capacitance Compensation When Using Switching Matrix"
- "Maintenance"
- "About Plug-in Modules"

To change the GPIB address of the B1500A, see "To Change GPIB Address" on page 3-10. To control external GPIB devices from the B1500A/EasyEXPERT, see "To Enable System Controller" on page 3-11.

WARNING **To avoid electrical shock and instrument damage, turn the instrument off before connecting or disconnecting measurement cable.**

WARNING **This instrument is heavy and requires a two person lift.**

CAUTION Do not grab the fixture cover when lifting the test fixture.

WARNING ⚠ **There are potentially hazardous voltages (± 200 V for HPSMU, and ± 100 V for MPSMU/HRSMU) present at the Force, Sense, and Guard terminals of this instrument. To prevent electrical shock, the following safety precautions must be observed during the use of the instrument.**

- **Use a three-conductor AC power cable to connect the instrument to an electrical ground (safety ground).**
- **If you do *not* use the B1500A-A5F/16442A/B test fixture, you must install and connect an interlock circuit that opens the Interlock terminal when the shielding box access door is opened.**
- **If you change the DUT interface, test fixture, prober, and such, connect an interlock cable to the one actually used.**
- **Confirm periodically that the interlock function works normally.**
- **Before touching the connections on the Force, Guard, and Sense terminals in the test fixture or the shielding box, turn the instrument off and discharge any capacitors. If you do *not* turn the instrument off, complete *all* of the following items, regardless of the instrument settings.**
  - **Press the front panel Stop key to set the module output off.**
  - **Confirm that the front panel High Voltage indicator is not lit.**
  - **Open the Interlock terminal (open the fixture cover or the shielding box access door).**
  - **Discharge any capacitors connected to a measurement resource.**
- **Warn persons working around this instrument about dangerous conditions.**

Requirements

This section contains information on:

- "Power Requirements"
- "Operating Environment"
- "Storaging/Shipping Environment"
- "Installation Requirements"
- "Power Cable"

Power Requirements

This instrument can operate from any single-phase AC power source supplying 100-240 V (±10 %) at 50/60 Hz. The maximum power consumption is 900 VA.

Operating Environment

This instrument is specified to operate within the following environmental conditions:

Temperature: 5 °C to 40 °C

Humidity: 20 % to 70 % RH, non-condensing

Altitude: 0 to 2,000 m (6,561 ft.)

Storaging/Shipping Environment

This instrument is specified to store/ship within the following environmental conditions:

Temperature: -20 °C to 60 °C

Humidity: 10 % to 90 % RH, non-condensing

Altitude: 0 to 4,600 m (15,092 ft.)

Installation Requirements

WARNING **Do not operate the instrument in dusty environment, or in the presence of flammable gasses, corrosive gasses, or fumes.**

- Environmental conditions for this instrument are documented in "General Specifications" on page 4-51. In principle, this instrument should only be operated indoors in a controlled environment.
- Install the instrument horizontal place then face the roof up.
- The dimensions of this instrument are also given in "General Specifications". Fan cools the instrument by drawing air through the sides and exhausting it out the back. The instrument must be installed in a location that allows sufficient space at the sides and back of the instrument for adequate air circulation.

  If the airflow is restricted, the internal operating temperature will be higher. This may reduce the instrument's reliability, or cause the thermal-protection circuits to turn the instrument off.
- Make sure that there is enough space for connecting/disconnecting the power cable easily.

Power Cable

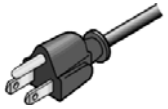
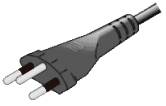
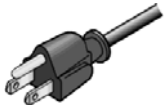
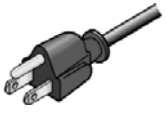
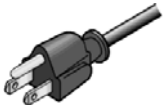
WARNING **FIRE HAZARD: Use only the power cable supplied with your instrument. Using other types of power cable may cause overheating of the power cable, resulting in fire.**

SHOCK HAZARD: The power cable provides the chassis ground through a third conductor. Be sure to connect to a three-conductor type power outlet with the correct pin grounded.

NOTE The detachable power cable may be used as an emergency disconnecting device. Removing the power cable will disconnect AC input power to the instrument.

Connect the power cable to the IEC 320 connector on the rear of the instrument. If the wrong power cable was shipped with your instrument, contact your nearest Keysight Sales and Support Office.

The AC input on the back of your instrument is a universal AC input. It accepts nominal line voltages in the range of 100 to 240 VAC.

Option 900 • Plug: BS 1363/A, 250 V, 10 A • PN: 8120-4420	Option 901 • Plug: AS/NZS 3112, 250 V, 10 A • PN: 8120-4419	Option 902 • Plug: IEC 60277-1, 250 V, 10 A • PN: 8121-1226	Option 903  • Plug: NEMA 5-15P, 125 V, 10 A • PN: 8120-6825
Option 904 • Plug: NEMA 6-15P, 250 V, 10 A • PN: 8120-3996	Option 906  • Plug: SEV 1011, 250 V, 10 A • PN: 8120-4416	Option 912 • Plug: SB 107-2-D1, 250 V, 10 A • PN: 8121-1655	Option 917 • Plug: IS 1293 and IS 6538, 250 V, 10 A • PN: 8121-1690
Option 918  • Plug: JIS C 8303, 125 V, 12 A • PN: 8121-0743	Option 919 • Plug: Israel SI 32, 250 V, 10 A • PN: 8121-0724	Option 920 • Plug: IRAM 2073, 250 V, 10 A • PN: 8121-0725	Option 921 • Plug: CEI 23-16, 250 V, 10 A • PN: 8121-0722
Option 922 • Plug: GB 1002 figure 3, 250 V, 10 A • PN: 8120-8376	Option 923 • Plug: SANS 164-1, 250 V, 10 A • PN: 8121-0564	Option 927  • Plug: NEMA WD-6, 250 V, 10 A • PN: 8120-0674	Option 930 • Plug: NBR 14136, 250 V, 10 A • PN: 8121-1809
Option 931  • Plug: CNS 10917-2, 125 V, 10 A • PN: 8121-1635	Option 932 • Plug: CS 0017, 250 V, 10 A • PN: 8121-1638		

Inspection and Installation

This section describes what to do when you receive the instrument and accessories.

1. Inspect the shipment. See "To Inspect B1500 and Accessories".
2. Verify the instrument operation and perform initial setup. See "To Perform Initial Setup".
3. Install the instrument in the appropriate place. See "Requirements" on page 3-4.

To use the instrument briefly, see "Getting Started" on page 1-1.

To change the Windows logon setting, see "To Change Windows Logon Setting" on page 3-9.

To change the GPIB address of the instrument, see "To Change GPIB Address" on page 3-10.

To allow the B1500A/EasyEXPERT to control external GPIB devices, see "To Enable System Controller" on page 3-11.

To Inspect B1500 and Accessories

Perform the following inspections when the instrument and accessories arrive at your site.

1. Before unpacking any components, inspect all boxes for any signs of damage that might have occurred during shipment, such as:

   - dents
   - scratches
   - cuts
   - water marks

   If you suspect any damage, notify your local Keysight Technologies sales or service office.

2. When you open the boxes that contain the instrument and accessories, check the components against the contents lists attached to the boxes.

   If anything is missing, notify your local Keysight Technologies sales or service office.

To Perform Initial Setup

After you receive the instrument, perform the following setup.

For the users available just after the initial setup, see Table 3-1.

1. Make sure that the Standby switch is set to off.
2. On the instrument rear panel, connect the Circuit Common terminal to the frame ground terminal by using a shorting-bar.
3. If you use Keysight 16444A-001 USB keyboard and/or the 16444A-002 USB mouse, connect it to an USB port of the instrument.
4. Connect the power cable from the instrument to an AC power outlet.
5. Open the measurement terminals and press the Standby switch to turn on the instrument.

   If the instrument is operating correctly, the power-on self-test is automatically performed. If problems arise, see Keysight EasyEXPERT *User's Guide*.
6. Follow the Windows setup wizard and complete the initial setup.

   a. Set the system display language to English. The language must be English. If you set another language, you must perform the system recovery of the B1500A. See Keysight EasyEXPERT *User's Guide* for the system recovery.

   b. Set Country or region, Time and currency, and Keyboard layout.

      If you use the 16444A-001 USB keyboard, the Keyboard layout must be US.

   c. Accept the End User License Agreement.

   d. Set Time zone, date and time.

   If the instrument has been already connected to your site LAN, you can proceed the network connection setup.

NOTE

Other Windows setup

You can set other setup of Windows after the initial setup. It is your responsibility.

If you connect the instrument to the network, take care to protect it from computer virus.

Table 3-1 **Users Available Just After the Initial Setup**

User Account	Description
Keysight B1500 User	Account for automatic logon. Password is not set to this account.
keysightOnly	Account for Keysight service personnel. Do not delete this account. This account is password protected.
Administrator	Administrator. Password is not set to this account.

You can add users after the initial setup. Add users as you need.

NOTE Keysight Technologies cannot guarantee the performance and provide compatibility information for all B1500As under several conditions. If problems arise, perform Keysight B1500A system recovery.

To perform recovery, see Keysight EasyEXPERT *User's Guide*.

To Change Windows Logon Setting

Keysight B1500A initially enables Windows automatic logon. If you want to change this setting, select *All Programs* > *Control Auto Logon* from the Start menu. Control Auto Logon is displayed on the browser. Then click one of the following buttons on the browser and follow the setup script.

- Enable Auto Logon
- Disable Auto Logon

NOTE If you set a password for the user account *Keysight B1500 User*, disable the automatic logon.

To Change GPIB Address

When this instrument is shipped from the factory, the GPIB address is set to 17. To change the GPIB address, perform the following procedure.

1. If the EasyEXPERT software is running, terminate it as shown below:
   a. Select the menu function *File* > *Exit* on the EasyEXPERT main screen.
   b. Click [x] at the upper right corner of the Start EasyEXPERT button.
2. Select *All Programs* > *Keysight IO Libraries Suite* > *Keysight Connection Expert* from the Start menu. Keysight Connection Expert window appears.
3. At the *Instrument I/O on this PC* area, select GPIB0, and click the Change Properties... button. Keysight 82350 PCI GPIB Interface - GPIB0 window appears.
4. Change the GPIB Address value.
5. Remove the check from the *Auto-discover instruments connected to this interface* box.
6. Click the OK button on Keysight 82350 PCI GPIB Interface - GPIB0 window.
7. If the Reboot Required dialog box is displayed, click the Reboot Now button, and reboot the instrument.

To Enable System Controller

To allow Keysight B1500A/EasyEXPERT to control external GPIB devices, perform the following procedure.

1. If the EasyEXPERT software is running, terminate it as shown below:
   a. Select the menu function *File* > *Exit* on the EasyEXPERT main screen.
   b. Click [x] at the upper right corner of the Start EasyEXPERT button.
2. Select *All Programs* > *Keysight IO Libraries Suite* > *Keysight Connection Expert* from the Start menu. Keysight Connection Expert window appears.
3. At the *Instrument I/O on this PC* area, select GPIB0, and click the Change Properties... button. Keysight 82350 PCI GPIB Interface - GPIB0 window appears.
4. Set the GPIB Address value to 21 that is the typical address number for the system controller.
5. Check the *System Controller* box.
6. Remove the check from the *Auto-discover instruments connected to this interface* box.

   This disables the automatic device detection. So the Connection Expert cannot detect the instruments connected to the GPIB interface by itself.
7. Click the OK button on Keysight 82350 PCI GPIB Interface - GPIB0 window.
8. If the Reboot Required dialog box is displayed, click the Reboot Now button, and reboot the instrument.

NOTE

To Disable System Controller

If the B1500A is the system controller, you cannot control the B1500A by using an external computer. To disable the system controller, change the steps 4 and 5 for setting the GPIB Address value to *not* 21 and removing the check from the *System Controller* box, and perform the procedure to the step 8.

Installing Accessories

This section describes how to install the accessories.

- "To Connect 16442B Test Fixture (B1500A-A5F)"
- "To Connect Connector Plate"
- "To Connect ASU"
- "To Connect SCUU/GSWU"
- "To Connect GNDU Adapter"
- "To Connect MCSMU Connection Box"

WARNING **To avoid electrical shock and instrument damage, turn the instrument off before connecting or disconnecting measurement cable.**

WARNING **There are potentially hazardous voltages (± 200 V for HPSMU, and ± 100 V for MPSMU/HRSMU) present at the Force, Sense, and Guard terminals. To prevent electrical shock, do *not* expose these lines.**

WARNING **This instrument supports the Interlock function to prevent you from receiving an electrical shock from high voltage (more than ± 42 V). If the Interlock terminal is open, this instrument *cannot* apply high voltage more than ± 42 V.**

If you do not use the 16442A/B test fixture, install an interlock circuit (see page 31) and connect it to the Interlock terminal.

CAUTION The GNDU can sink current of up to 4.2 A. Use Keysight 16493L GNDU cable to connect the GNDU to a test fixture or a connector plate.

Do *not* use normal triaxial cable (Keysight 16494A) because the maximum current rating of the cable is 1 A.

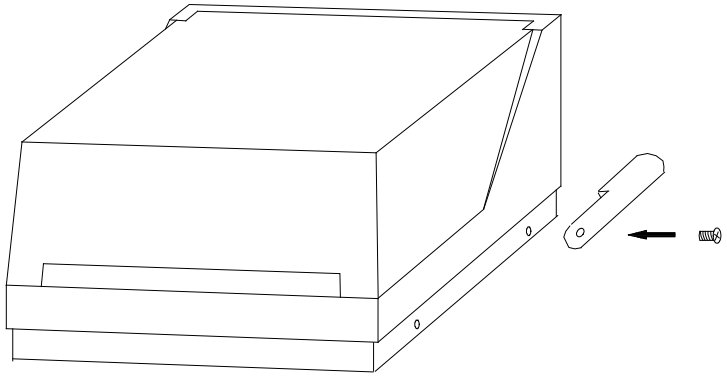
CAUTION Never connect the Guard terminal to any output, including circuit common, chassis ground, or any other guard terminal. Doing so will damage the SMU.

To Connect 16442B Test Fixture (B1500A-A5F)

See this section if you use Keysight 16442B test fixture (B1500A-A5F). This section describes how to set up the 16442B and how to connect the B1500A to the 16442B.

To Set up 16442B (B1500A-A5F)

You can stabilize the 16442B (B1500A-A5F) as shown in the figure below.



1. Put a stabilizer on both sides of the test fixture.
2. Attach each stabilizer to the test fixture with a flathead screw.

To Connect 16442B (B1500A-A5F)

Use the cables shown in Table 3-2 to connect from the B1500A connectors to the 16442B's relative connectors.

NOTE

Making non-Kelvin connection

The Force terminals can be used to force and measure DC voltage or current. If you want to simplify the cable connections, open the Sense terminals and connect the Force terminals only to the test fixture by using the triaxial cables.

If you make the Kelvin connection (remote sensing), use both Force and Sense terminals. Connecting the Force and Sense lines together at the terminal of the device under test minimizes the measurement error caused by the residual resistance of the connection cables. The Kelvin connection is effective for the low resistance measurement and the high current measurement.

Table 3-2 To Connect 16442B (B1500A-A5F)

Cables	16442B Terminals	B1500A Terminals	
Keysight 16493J Interlock Cable, 3 m or 1.5 m	Intlk	Interlock	
Keysight 16493L GNDU Cable, 3 m or 1.5 m	GNDU	GNDU	
Keysight 16493K Kelvin Triaxial Cable, 3 m or 1.5 m, for the Kelvin connection Up to 3 SMUs can be connected to the 16442B by the Kelvin connection.	SMU1	SMU	Force
	SMU2		Sense
	SMU3	SMU	Force
	SMU4		Sense
	SMU5	SMU	Force
	SMU6		Sense
Keysight 16494A Triaxial Cable, 3 m or 1.5 m, for the non-Kelvin connection	SMU1	SMU	Force
	SMU2	SMU	Force
	SMU3	SMU	Force
	SMU4	SMU	Force
	SMU5	SMU	Force
	SMU6	SMU	Force
Keysight 16493P SPGU Cable, 3 m or 1.5 m	PGU1	SPGU	Output 1
	PGU2		Output 2
Keysight N1300A CMU Cable[a], 3 m or 1.5 m	PGU1	CMU	Hcur/Hpot
	PGU2		Lcur/Lpot

a. To extend the four-terminal pair (4TP) connection to the 16442B inputs, connect the Hcur and Hpot cables together and the Lcur and Lpot cables together by using the BNC T-type adapter (female-female-male, Keysight part number 1250-2405), then connect them to the 16442B inputs.
To extend the 4TP connection to the socket module inputs, connect the cables to the PGU1, PGU2, VSU1, VSU2, VMU1, or VMU2 connector individually, and connect the Hcur and Hpot terminals together and the Lcur and Lpot terminals together at the socket module inputs.
It is ok to leave open the ground wire extended from the CMU cable.

To Connect Connector Plate

The available connector plates are listed in Table 3-3. Option 001 provides the through connectors except for the Interlock connector that provides the soldering patterns at the back side. For the option 002, the back of each connector is designed for soldering. For connector plate installation information, see *Keysight 16495 Installation Guide*.

For the 16495H/J, the insulator is inserted between the panel and the outer conductor of Triax connectors/BNC connectors.

Use the cables shown in Table 3-4 to connect from the B1500A connectors to the connector plate's relative connectors. For the cable connections from the connector plate to the DUT interface such as manipulator and probe card, see "Mounting Connectors" on page 3-29 as reference.

NOTE

Making non-Kelvin connection

The Force terminals can be used to force and measure DC voltage or current. If you want to simplify the cable connections, open the Sense terminals and connect the Force terminals only to the connector plate by using the triaxial cables.

If you make the Kelvin connection (remote sensing), use both Force and Sense terminals. Connecting the Force and Sense lines together at the terminal of the device under test minimizes the measurement error caused by the residual resistance of the connection cables. The Kelvin connection is effective for the low resistance measurement and the high current measurement.

Table 3-3 Connector Plates

Model	Option Item	Connectors
16495F	16495F-001	Triax. (f-f) ×12, GNDU (f-f) ×1, Interlock (f) ×1
	16495F-002	Triax. (f) ×12, GNDU (f) ×1, Interlock (f) ×1
16495G	16495G-001	Triax. (f-f) ×24, GNDU (f-f) ×1, Interlock (f) ×1
	16495G-002	Triax. (f) ×24, GNDU (f) ×1, Interlock (f) ×1
16495H	16495H-001	Triax. (f-f) ×6, Coax. (f-f) ×6, GNDU (f-f) ×1, Interlock (f) ×1
	16495H-002	Triax. (f) ×6, Coax. (f) ×6, GNDU (f) ×1, Interlock (f) ×1
16495J	16495J-001	Triax. (f-f) ×8, Coax. (f-f) ×4, GNDU (f-f) ×1, Interlock (f) ×1
	16495J-002	Triax. (f) ×8, Coax. (f) ×4, GNDU (f) ×1, Interlock (f) ×1
16495K	16495K-001	Connector plate, rubber holder

Table 3-4 To Connect Connector Plate

Cables	Connector Plate	B1500A Terminals	
Keysight 16493J Interlock Cable, 3 m or 1.5 m	Intlk	Interlock	
Keysight 16493L GNDU Cable, 3 m or 1.5 m	GNDU	GNDU	
Keysight 16493K[a] Kelvin Triaxial Cable, 3 m or 1.5 m, for the Kelvin connection 16495F provides the inputs 1 to 12 (6 Kelvin). 16495H provides the inputs 1 to 6 (3 Kelvin). 16495J provides the inputs 1 to 8 (4 Kelvin).	odd number	SMU	Force
	even number		Sense
Keysight 16494A Triaxial Cable, 3 m or 1.5 m, for non-Kelvin connection 16495H provides the inputs 1 to 6. 16495J provides the inputs 1 to 8.	odd number or even number	SMU	Force
Keysight 16493P SPGU Cable, 3 m or 1.5 m 16495H provides the inputs 7 to 12. 16495J provides the inputs 9 to 12.	odd number or even number	SPGU	Output 1
			Output 2
Keysight N1300A CMU Cable[b], 3 m or 1.5 m 16495H provides the inputs 7 to 12. 16495J provides the inputs 9 to 12.	odd number or even number	CMU	Hcur/Hpot
			Lcur/Lpot

a. Use Keysight 16494B Kelvin Triaxial Cable to connect to Keysight E5250A Low Leakage Switch Mainframe or the connector plate for Keysight 4142B Modular DC Source/Monitor by the Kelvin connection.

b. To extend the four-terminal pair (4TP) connection to the connector plate inputs, connect the Hcur and Hpot cables together and the Lcur and Lpot cables together by using the BNC T-type adapter (female-female-male, Keysight part number 1250-2405), then connect them to the connector plate inputs. To extend the 4TP connection to the DUT interface, connect the cables to the connector plates input connectors individually, and connect the Hcur and Hpot terminals together and the Lcur and Lpot terminals together on the DUT interface. See Figure 3-21.
It is ok to leave open the ground wire extended from the CMU cable.

To Connect ASU

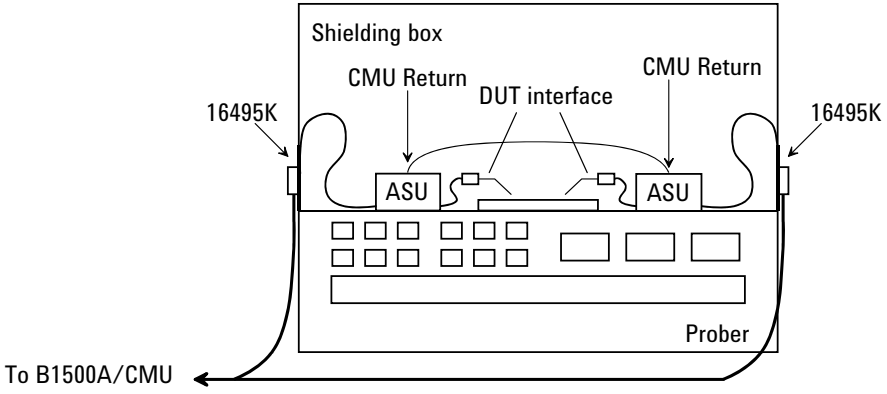
Keysight E5288A Atto Sense and Switch Unit (ASU) adds the following functions to the B1500A. To use the ASU, it must be connected to the SMU which is connected together when the calibration is performed.

- Atto ampere (aA) level current measurement capability
- Automatic switching of ASU input resource connected to ASU output

NOTE

For the installation of the ASU and the connection to the DUT interface (probe card, manipulators, and so on), contact your favorite prober vender. The prober vender will have the solutions. Dimensions of the ASU are 132 mm (W) × 88.5 mm (H) × 50 mm (D) excluding the connectors.

Figure 3-1 **Image of ASU Installation**



Required parts

- Keysight 16495K Connector plate
- Keysight 16493M ASU cable
- Keysight N1300A CMU cable or Keysight 16048D/E test leads
- Keysight N1254A-108 Magnet stand
- BNC cable, coaxial cable, manipulator, wire, and so on

To install 16495K

Fix the 16495K plate to the shielding box or something that will cover the DUT interface. See *Keysight 16495 Installation Guide*. The 16495K is the plate that has the mechanism to block the light from the cable hole used to pass the cables in the shielding box.

To install ASU

1. Fix the ASU in the shielding box. The ASU must be fixed to the best position for accessing its connectors. Keysight N1254A-108 Magnetic Stand will be useful for fixing the ASU.
2. Pass the 16493M (D-sub cable, triaxial cable), N1300A CMU cable, 16048D/E test leads, BNC cable and so on through the cable hole of the 16495K. They will be connected between the ASU and the instruments
3. Connect the D-sub cable to the ASU D-sub connector.

   Connect the triaxial cable to the ASU Force terminal.

   Connect the cable to the ASU CMU-cur/AUX In terminal. See Figure 3-2.

   - For the MFCMU, connect the N1300A CMU cable.
   - For Keysight 4284A/E4980A LCR meter, connect Keysight 16048D/E test leads.
   - For the instrument other than the MFCMU or the 4284A/E4980A, connect the BNC cable to the CMU-cur/AUX In terminal. And open the CMU-pot terminal or cover it by using the BNC open cap.
4. Adjust the cable length in the shielding box, and catch in the cables by using the cover of the 16495K.
5. Connect the cable from the DUT interface to the ASU output terminal.

   For the non Kelvin connection, open the Sense terminal or cover it by using the triaxial open cap.

To connect B1500A

1. Turn the B1500A off.
2. Connect the D-sub cable from the ASU to the SMU D-sub connector.
3. Connect the triaxial cable from the ASU to the SMU Force terminal.

NOTE

To use the ASU, it must be connected to the SMU which is connected together when the calibration is performed. The specifications are satisfied and guaranteed in this condition only. So confirm the serial number of the ASU and connect it to the dedicated SMU properly. See Keysight EasyEXPERT *User's Guide* to confirm the serial number.

To connect MFCMU/4284A/ E4980A to AUX

Perform the following procedure to connect the MFCMU or the 4284A/E4980A. See Figure 3-2 and Figure 3-3.

Prepare a shorting bar furnished with the ASU. The shorting bar is effective for reducing the offset capacitance caused by connecting a measurement terminal to the chuck of a wafer prober.

1. Turn the instrument off.
2. Prepare two ASUs (#1 and #2) and two shorting bar. And perform the following procedure for each ASU.
   a. Disconnect the triaxial cable from the ASU if it is connected to the ASU Force terminal.
   b. Face the concave side of the shorting bar to front.
   c. Slide the shorting bar from the right side of the connectors.
3. Connect the cable to the instrument. For the MFCMU, use the N1300A CMU cable. For the 4284A/E4980A, use the 16048D/E test leads. It is ok to leave open the ground wire extended from the cable.
4. Connect the high potential (Hp) cable of the test leads to the ASU #1 CMU-pot terminal.
5. Connect the high current (Hc) cable to the ASU #1 CMU-cur/AUX In terminal. The shorting bar is fixed to the ASU #1 by the step 5 and 6.
6. Connect the triaxial cable from the SMU #1 Force terminal to the ASU #1 Force terminal.
7. Connect the low potential (Lp) cable to the ASU #2 CMU-pot terminal.
8. Connect the low current (Lc) cable to the ASU #2 CMU-cur/AUX In terminal. The shorting bar is fixed to the ASU #2 by the step 8 and 9.
9. Connect the triaxial cable from the SMU #2 Force terminal to the ASU #2 Force terminal.
10. Prepare the connection wire (both pin terminals) furnished with the ASU and connect it between the CMU Return terminals of the ASU #1 and ASU #2 together.

NOTE

About ASU output cables

To perform capacitance measurements accurately, the cable length between DUT and the ASU output must be as short as possible.

Figure 3-2 **To Connect ASU**

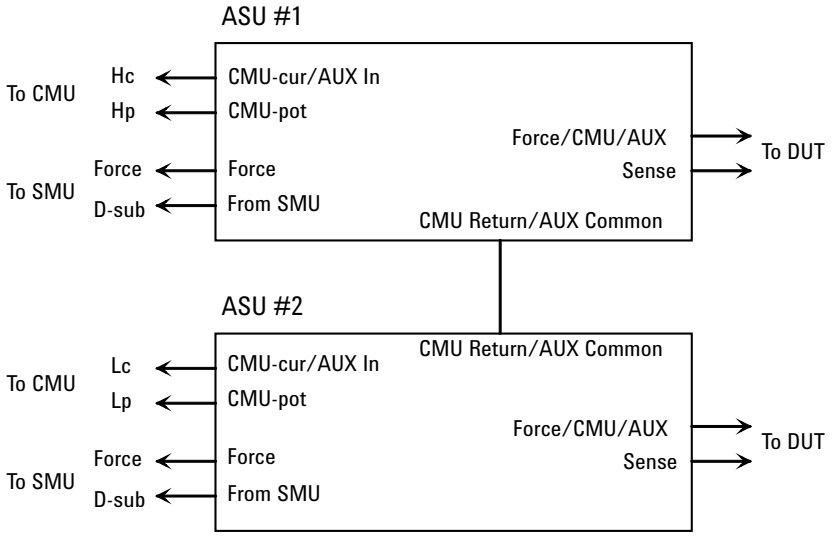
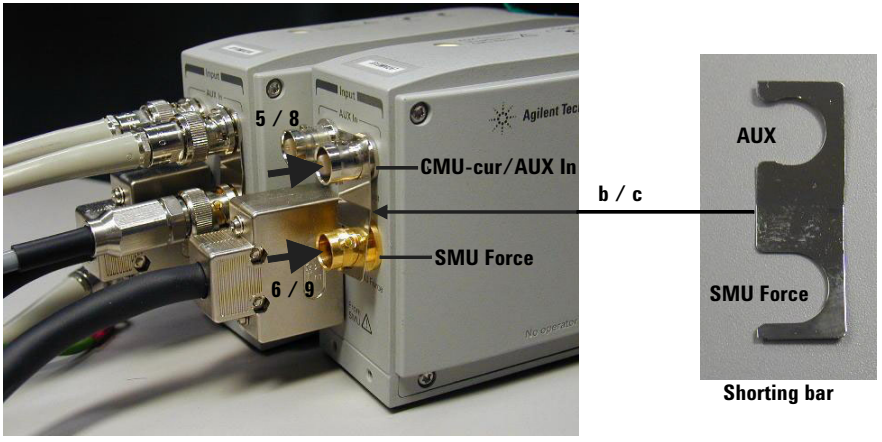


Figure 3-3 **To Set Shorting Bar**



To connect other instrument to AUX

To connect the instrument other than the MFCMU or the 4284A/E4980A:

1. Turn the instrument off.
2. Connect the BNC cable from the ASU CMU-cur/AUX In terminal to the instrument. Prepare an adapter if the instrument's input/output connector is not BNC.

To Connect SCUU/GSWU

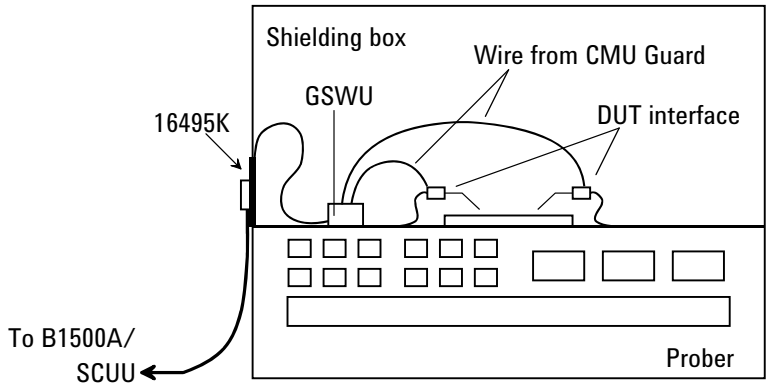
Keysight N1301A-100 SMU CMU Unify Unit (SCUU) is used to switch the measurement resource (CMU or SMU) to be connected to the DUT.

Keysight N1301A-200 Guard Switch Unit (GSWU) is used to connect the CMU high and low guard lines together near the DUT. The connection is broken when the SCUU is in the SMU connection state. The GSWU is effective for the accurate impedance measurement.

NOTE

For the installation of the SCUU/GSWU and the connection to the DUT interface (probe card, manipulators, and so on), contact your favorite prober vender. The prober vender will have the solutions. Dimensions of the SCUU are 148 mm (W) × 75 mm (H) × 70 mm (D). Dimensions of the GSWU are 33.2 mm (W) × 41.5 mm (H) × 32.8 mm (D).

Figure 3-4 **Image of GSWU Installation**



Required parts

- Keysight 16495K Connector plate
- Keysight N1301A-201/202 GSWU cable (if GSWU is used)
- Keysight N1301A-102 SCUU cable (if SCUU is not attached to the MFCMU)
- Keysight N1301A-110 Magnet stand (if GSWU is used)
- BNC cable, coaxial cable, manipulator, wire, and so on

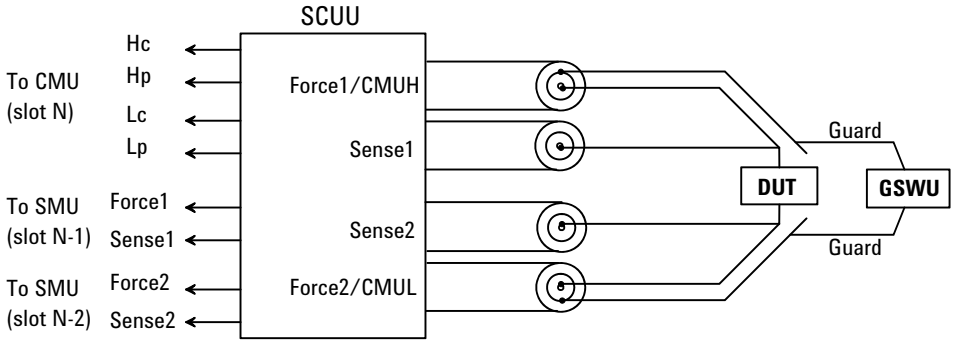
To install 16495K

Fix your necessary 16495 connector plates to the shielding box or something that will cover the DUT interface. See *Keysight 16495 Installation Guide*. For the GSWU installation, the 16495K is required. It is the plate that has the mechanism to block the light from the cable hole used to pass the cables in the shielding box.

Before starting

1. GSWU is furnished with wires (2 ea.) for the connection between the GSWU and the DUT interface Guard terminal. If it is too short to connect them, prepare additional wire.
2. Turn the B1500A off.

Figure 3-5 To Connect SCUU/GSWU



To connect SCUU/GSWU 1

To attach the SCUU to the B1500A:

1. Attach the SCUU to the B1500A rear panel connectors for the MFCMU in the slot N and two SMUs in the slots N-1 and N-2 (N: integer, 3 to 10).

   Connection will be easy by bringing the control connectors together before bringing the BNC connectors.

2. Fix the GSWU in the shielding box. The GSWU must be fixed to the best position for accessing its connectors.
3. Pass the GSWU cable (Keysight N1301A-201/202) through the cable hole of the 16495K. And connect it between the SCUU and the GSWU.
4. Adjust the cable length in the shielding box, and catch in the cables by using the cover of the 16495K.
5. Connect the proper cables from Force1/CMUH and Force2/CMUL to the 16495 connector plates or the DUT interface. See Figure 3-5.

   For the Kelvin connections, also connect the proper cables from Sense1 and Sense2 to the 16495 connector plates or the DUT interface.

6. Connect the wires (furnished, 2 ea.) to the GSWU.
7. Connect one of the wires to the Guard terminal extended from CMUH of SCUU. Then the wire should contact the Guard terminal as close to the device as possible.
8. Connect another one to the Guard terminal extended from CMUL of SCUU. Then the wire should contact the Guard terminal as close to the device as possible.

NOTE

About SCUU output cables

To perform capacitance measurements accurately, the cable length between DUT and the SCUU output must be as short as possible.

To connect SCUU/GSWU 2

1. Attach an end of the SCUU cable (Keysight N1301A-102) to the SCUU.

   Connection will be easy by putting the SCUU and the cable connection box on the flat table, and bringing the control connectors together before bringing the BNC connectors.

   If the SCUU is fixed inside the shielding box, pass the SCUU cable through the cable hole of the 16495K.

2. Fix the SCUU inside or outside the shielding box. The SCUU must be fixed to the best position for accessing its connectors. Keysight N1301A-110 Magnetic Stand will be useful for fixing the SCUU.
3. Attach the other end of the SCUU cable to the B1500A rear panel connectors for the MFCMU in the slot N and two SMUs in the slots N-1 and N-2 (N: integer, 3 to 10).

   Connection will be easy by bringing the control connectors together before bringing the BNC connectors.
4. Fix the GSWU in the shielding box. The GSWU must be fixed to the best position for accessing its connectors.
5. Connect the GSWU cable (Keysight N1301A-201/202) between the SCUU and the GSWU.

   If the SCUU is fixed outside the shielding box, pass the GSWU cable through the cable hole of the 16495K.
6. Adjust the cable length in the shielding box, and catch in the cables by using the cover of the 16495K.
7. Connect the proper cables from Force1/CMUH and Force2/CMUL to the 16495 connector plates or the DUT interface. See Figure 3-5.

   For the Kelvin connections, also connect the proper cables from Sense1 and Sense2 to the 16495 connector plates or the DUT interface.
8. Connect the wires (furnished, 2 ea.) to the GSWU.
9. Connect one of the wires to the Guard terminal extended from CMUH of SCUU. Then the wire should contact the Guard terminal as close to the device as possible.
10. Connect another one to the Guard terminal extended from CMUL of SCUU. Then the wire should contact the Guard terminal as close to the device as possible.

NOTE

About SCUU output cables

To perform capacitance measurements accurately, the cable length between DUT and the SCUU output must be as short as possible.

To Connect GNDU Adapter

The ground unit (GNDU) output is the single triaxial connector. To change it to the dual triaxial connector, use Keysight N1254A-100 GNDU to Kelvin Adapter. The adapter and cables are furnished with the B1500A.

Attach the adapter directly to the rear panel as shown below.

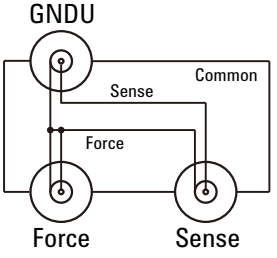
1. Face the adapter's GNDU connector and banana jack to the B1500A's GNDU connector and Circuit Common terminal respectively.
2. Push the adapter toward the B1500A.
3. Rotate the GNDU connector handle of the adapter to fix it to the B1500A.

Use the following cables to extend the GNDU Force and Sense terminals.

- 16493L GNDU cable, for Force
- 16494A Triaxial cable, for Sense

Figure 3-6 **GNDU to Kelvin Adapter**

Figure 3-7 **GNDU to Kelvin Adapter Internal Connections**



To Connect MCSMU Connection Box

Keysight N1255A connection box is used to make the connection of MCSMU easy. Input panel provides six triaxial connectors for connecting two MCSMU and one GNDU or SMU. Output panel provides six triaxial connectors for the High1, High2, and Low terminals. See Figure 3-10 for image of the Input panel and the Output panel. Also see Figure 3-8 for the connection image. And see Figure 3-9 for the internal connection.

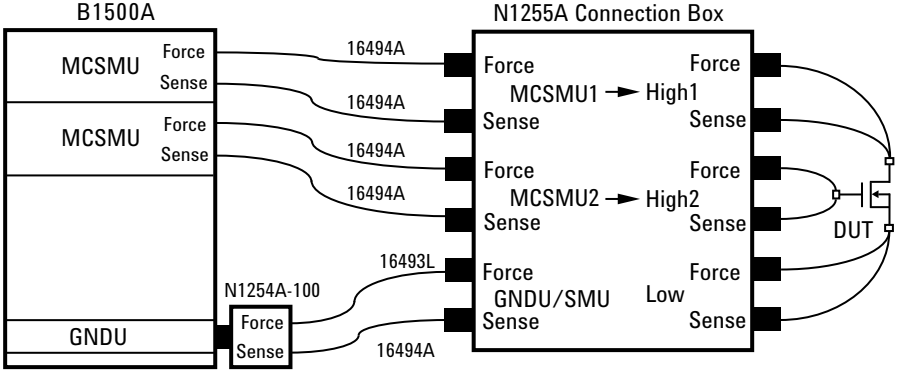
Use the following cables to connect the N1255A to the MCSMU.

- 16494A Triaxial cable, 2 ea. per one MCSMU

Use the following cables and adapter to connect the N1255A to the GNDU.

- N1254A-100 GNDU to Kelvin adapter, 1 ea.
- 16493L GNDU cable, 1 ea.
- 16494A Triaxial cable, 1 ea.

Figure 3-8 **N1255A Connection Example**



NOTE ⚠ N1255A Input and Output terminals

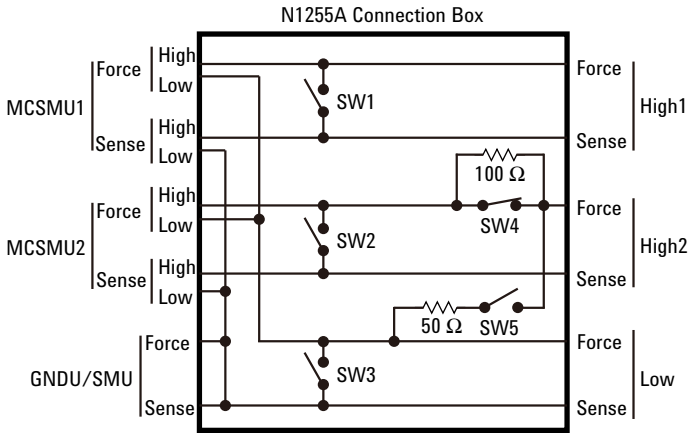
If a MP/HP/HRSMU is connected instead of the GNDU, use the following cable. Also, do not use the SMU current range less than 100 mA.

- 16494A Triaxial cable, 2 ea.

Voltage rating of terminal is indicated near connector on the Input or Output panel.

The N1255A cannot be used for measurement of the IEC Measurement Category II, III, or IV.

Figure 3-9 **N1255A Internal Connections**



- SW1: Kelvin/Non-Kelvin selection switch for High1
- SW2: Kelvin/Non-Kelvin selection switch for High2
- SW3: Kelvin/Non-Kelvin selection switch for Low
- SW4: 0 Ω/100 Ω series resistor selection switch for High2 Force
- SW5: Open/50 Ω shunt resistor selection switch between High2 and Low, Force

NOTE ⚠ Selection switch SW2 and SW4

The SW4 switches the series resistance 0 Ω/100 Ω on the High2 Force line. The resistor is not mounted on the High2 Sense line.

Set the SW4 to “0 Ω” if the SW2 is set to “Kelvin”.

Set the SW2 to “Non-Kelvin” if the SW4 is set to “100 Ω”.

NOTE ⚠ Selection switch SW1/SW2/SW3 and Sense connector on Output panel

The switch is used to make or break the connection between Force and Sense in the N1255A. Setting it to “Non-Kelvin” makes this internal connection to enable the non-Kelvin connection. And setting it to “Kelvin” breaks this internal connection to enable the Kelvin connection.

If the switch is set to “Non-Kelvin”, do not extend the Sense output corresponding to it. Voltage on the Force line also appears on the Sense line. So, open the Sense connector on the Output panel.

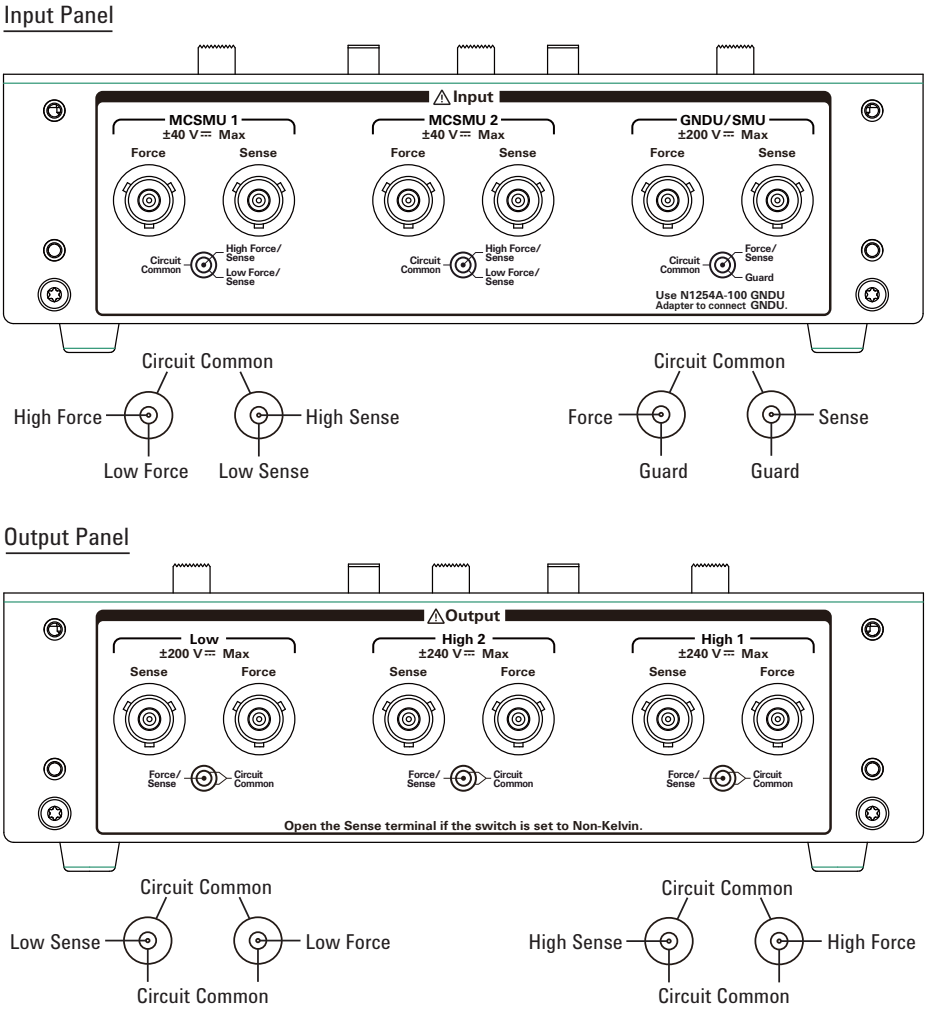
NOTE

Series Resistor and Shunt Resistor

The series resistor and the shunt resistor can be used for preventing MCSMU from oscillation. If the MCSMU oscillates, insert either 100 Ω series resistor or 50 Ω shunt resistor.

If it does not stop the oscillation, prepare the resistor of the other value and insert it between the Output High and the device under test (DUT).

Figure 3-10 N1255A Input Panel and Output Panel



Mounting Connectors

Previous sections described how to install the available accessories, and *Keysight 16495 Installation Guide* provides the information on how to install connector plates on the shielding box. However, you may choose to mount connectors directly on your own connector plate or test fixture.

To do this, you will need to make connector holes and mount the connectors yourself. This section contains information on connector hole dimensions.

To mount connectors:

1. Select and prepare the appropriate parts for your application. See Table 3-5.
2. Make the holes and mount the connectors. See Table 3-6.

   For Kelvin connections (remote sensing), use Keysight 16493K Kelvin triaxial cable. The Kelvin triaxial cable requires a Kelvin triaxial connector, which has two connector holes and three screw holes.
3. Build the interlock circuit shown in "To Make an Interlock Circuit" on page 3-31.
4. Attach cables from the connectors to the DUT (device under test). See "To Connect GNDU Output" on page 3-34, "To Connect SMU Output" on page 3-35, and "To Connect MFCMU Output" on page 3-42.

WARNING

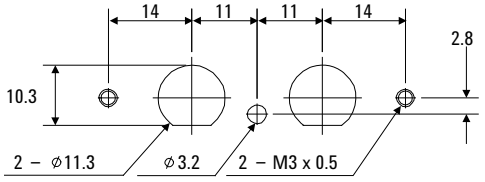
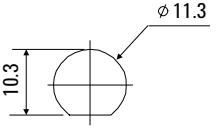
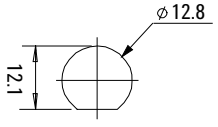
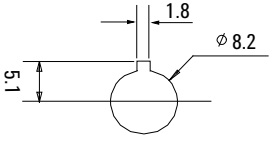
For safety, prepare and attach a shield cover to avoid touching the joints on the wiring side of connectors. And ground the cover.

Wrap an insulator around the naked conductors of coaxial cable to avoid touching it.

Table 3-5 Recommended Parts

Usage	Keysight Part No.	Description
Making an interlock circuit	1252-1419	Interlock Connector (6 pin, female)
	N1254A-402 or 3101-3241	Switch
	1450-0641	LED ($V_F \cong 2.1$ V @ $I_F = 10$ mA)
	8150-5680	Wire (24 AWG, 600 V, 150 °C)
Connecting GNDU to DUT	1250-2457	Triaxial Connector (female)
	8121-1189 or 8150-2639	Coaxial Cable or Wire
Connecting SMU to DUT	1250-2457	Triaxial Connector (female)
	8121-1191	Low Noise Coaxial Cable
Connecting MFCMU to DUT	1250-0118	BNC Connector (female)
	8120-0367	Coaxial Cable (50 Ω)
	8150-0447	Wire

Table 3-6 Dimensions of Connector Holes

Kelvin Triaxial Connector (in mm)	Triaxial Connector (in mm)
	
BNC Connector (in mm)	**Interlock Connector (in mm)**
	

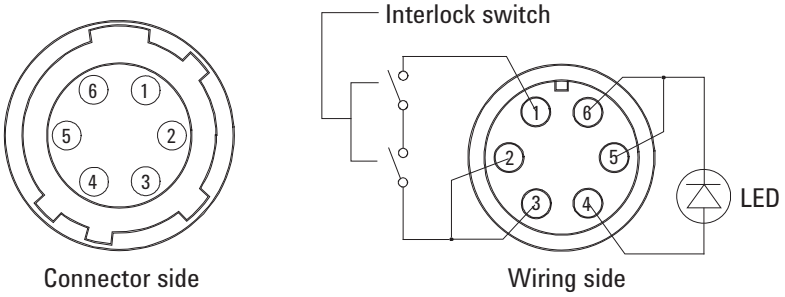
⚠ To Make an Interlock Circuit

The interlock circuit is designed to prevent electrical shock when a user touches the measurement terminals.

CAUTION You must install an interlock circuit on a shielding box to prevent hazardous voltages when the door of the shielding box is open.

Figure 3-11 shows the pin assignments of the interlock connector that should be mounted on a connector plate or test fixture.

Figure 3-11 Interlock Connector Pin Assignments



WARNING **Potentially hazardous voltages may be present at the Force, Guard, and Sense terminals when the interlock terminals are shorted.**

Installing the interlock circuit

Install the interlock circuit as follows:

1. Mount two mechanical switches on your shielding box, so that the switches close when the door of the shielding box is closed, and open when the door is opened. For the dimensions of the switch, see Figure 3-13 and Figure 3-14 below.
2. Mount an LED on your shielding box. For the dimensions of the LED, see Figure 3-12.
3. Use wire to connect the two switches in series between pin number 1 and 2 (or 3) of the interlock connector. See Figure 3-11.
4. Use wire to connect the LED between pin number 4 and 5 (or 6) of the interlock connector. See Figure 3-11.

If Keysight B1500A Interlock connector is connected to the interlock circuit, Keysight B1500A SMU *cannot* force more than ± 42 V when the door is open. When the door is closed, it can force more than ± 42 V.

When more than ± 42 V is forced from an SMU, the LED lights to indicate *high voltage output*.

Figure 3-12 **Dimensions of the LED (1450-0641)**

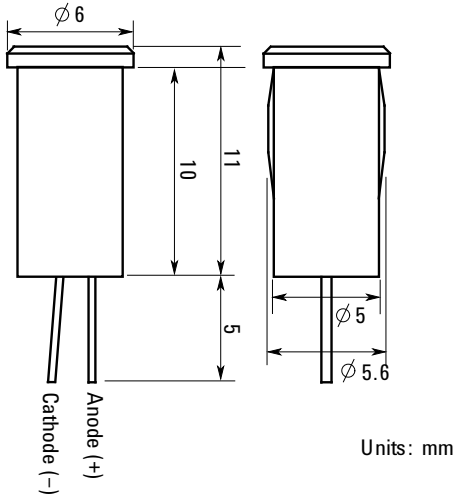


Figure 3-13 **Dimensions of the Interlock Switch (N1254A-402)**

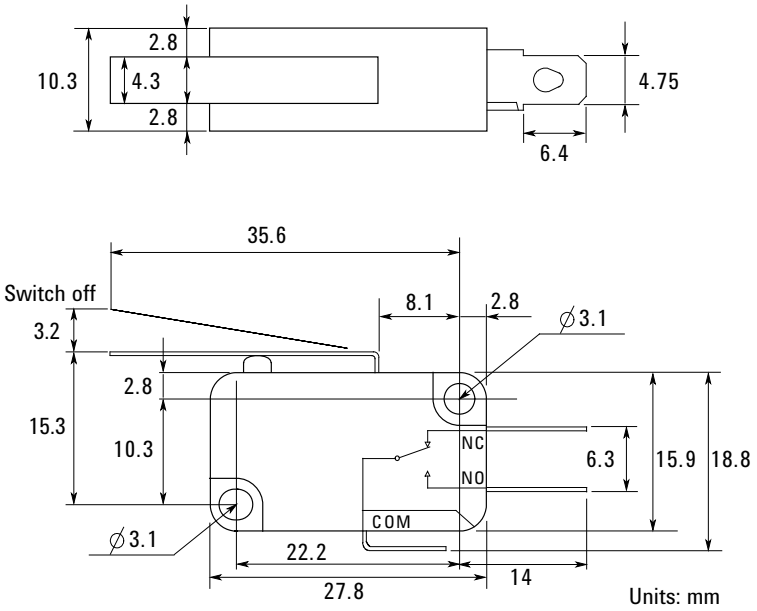
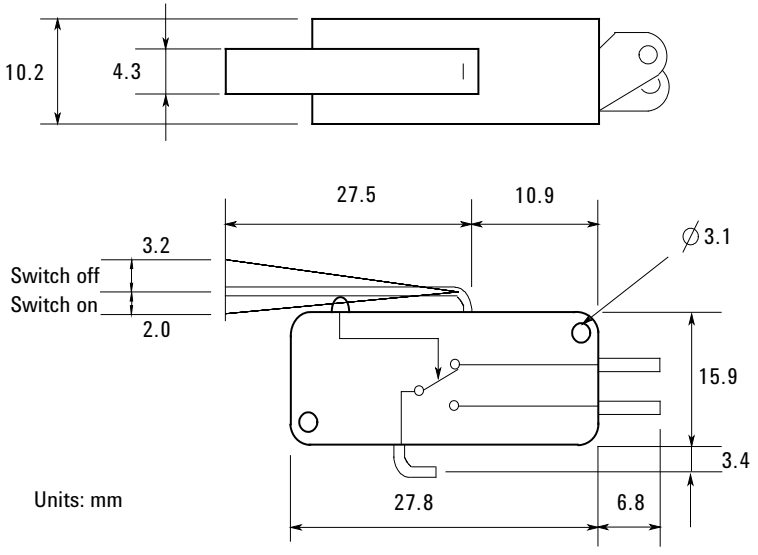


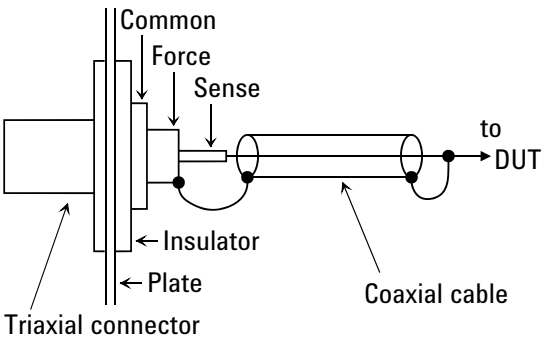
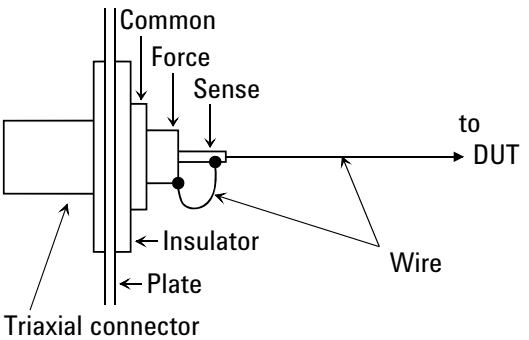
Figure 3-14 **Dimensions of the Interlock Switch (3101-3241)**



To Connect GNDU Output

The GNDU output connection examples are shown in Table 3-7

Table 3-7 GNDU Output Connections

Kelvin connections (remote sensing)	non-Kelvin connections
Use a low-noise coaxial cable (Keysight part number 8121-1189) from the connector to the prober, socket, or DUT as shown. To cancel the effects of cable resistance, connect the Sense line and Force line as close as possible to the terminal of the DUT.	Short the Sense and Force on the connector as shown below. Measurement data will include the residual resistance of the connection wire. Use AWG 22 single-strand insulated wire (Keysight part number 8150-2639) from the connector plate to the prober, socket, or DUT. For a quick connection where measurement accuracy is not critical, connect only Force to the DUT, without shorting the Sense and Force. With this connection, the measurement data will include residual resistance from the connection cable between the GNDU and the connector plate.
	

CAUTION

Use Keysight 16493L GNDU cable to connect the GNDU to your connector plate or test fixture. Do *not* use the triaxial cable. The GNDU is rated for up to 4.2 A, while the maximum current rating of the triaxial cable is 1 A.

To Connect SMU Output

The SMU output connection examples are shown in Table 3-8.

WARNING

There are potentially hazardous voltages (± 200 V for HPSMU, and ± 100 V for MPSMU/HRSMU) present at the Force, Sense, and Guard terminals.

To prevent electrical shock, do *not* expose these lines.

Before turning the instrument on, connect the Interlock terminal to an interlock circuit.

Before you touch any connections to these terminals, turn the instrument off, disconnect the power cable, and discharge any capacitors.

CAUTION

Never connect the Guard terminal to any output, including circuit common, chassis ground, or any other guard terminal. Doing so will damage the SMU.

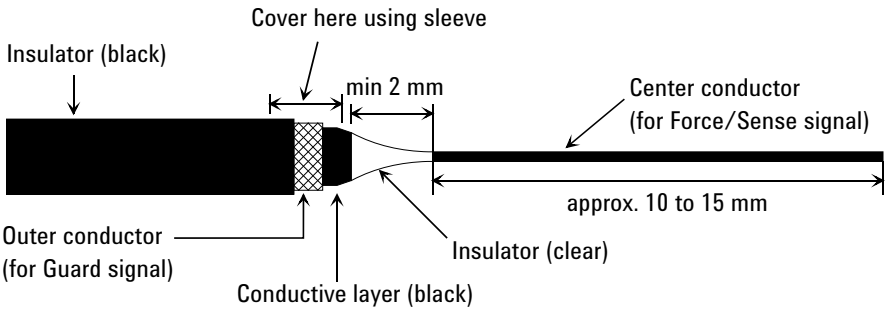
NOTE

Low-Noise Coaxial Cable

For the extended measurement paths over the connector plate, use low-noise coaxial cable (Keysight part number 8121-1191). This cable can maximize the guard effects and minimize the impression of the external noise.

Figure 3-15 shows the cutting example of this cable. Key point is the isolation between the conductive layer and the center conductor. So, cut and trim the end of the cable as shown in this figure by using a cutter and so on.

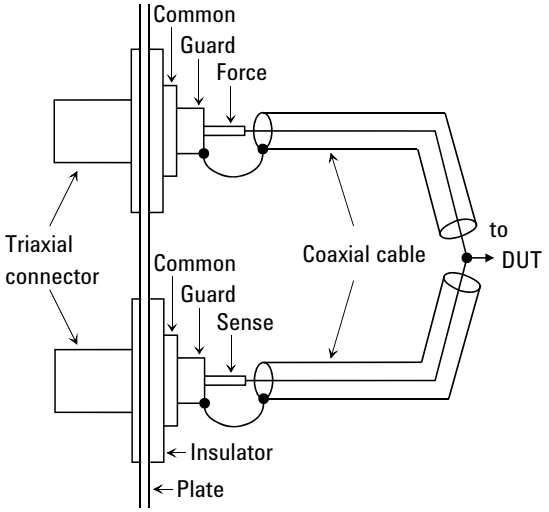
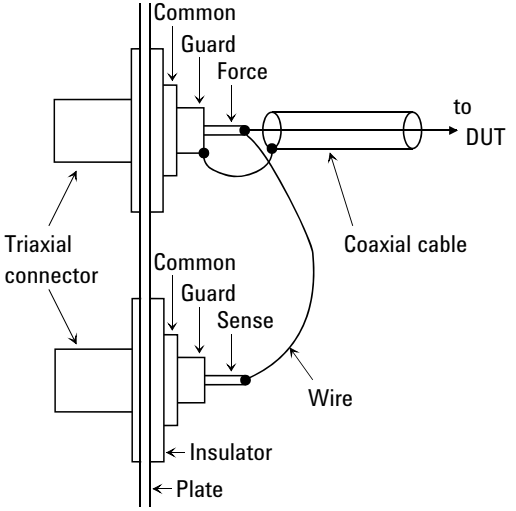
Figure 3-15 Coaxial Cable Cutting Example



WARNING

Wrap an insulator around the naked conductors of coaxial cable to avoid touching it.

Table 3-8 SMU Output Connections

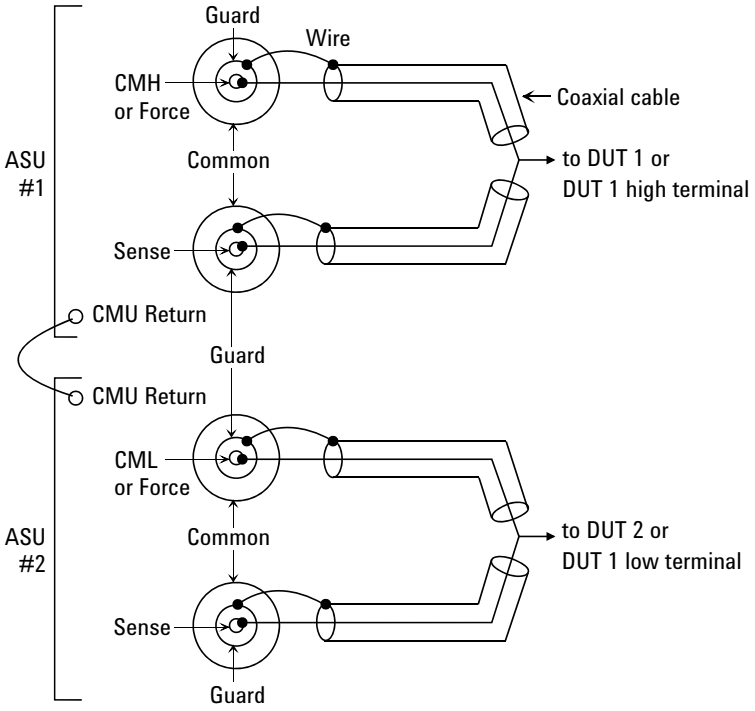
Kelvin connections (remote sensing)	non-Kelvin connections
Use low-noise coaxial cable (Keysight part number 8121-1191) from the connector to the prober, socket, or DUT as shown. See Figure 3-16 and Figure 3-18 for the ASU and SCUU connections respectively. To cancel the effects of cable resistance, connect the Sense line and Force line as close as possible to the DUT terminal. To prevent oscillations, do not use cables longer than 1.5 m.	Use low-noise coaxial cable (Keysight part number 8121-1191). The following figure is for the connection using Kelvin triaxial cable. For the connection using triaxial cable, connect the cable to the Force terminal only. In this connection, measurement data will include residual resistance from the connection cable. See Figure 3-17 and Figure 3-19 for the ASU and SCUU connections respectively.
	

NOTE

To Minimize Leakage Current

For the highly accurate current forcing and measurements, surround all force and sense lines by a guard as far as possible, and physically stable the cables with tape.

Figure 3-16 **ASU Output Kelvin Connection (Remote Sensing)**



The ASU inputs can be connected to the instruments by using a control cable, a triaxial cable, and two coaxial cables. The cables can be connected to the ASU inside the shielding box through the 16495K plate.

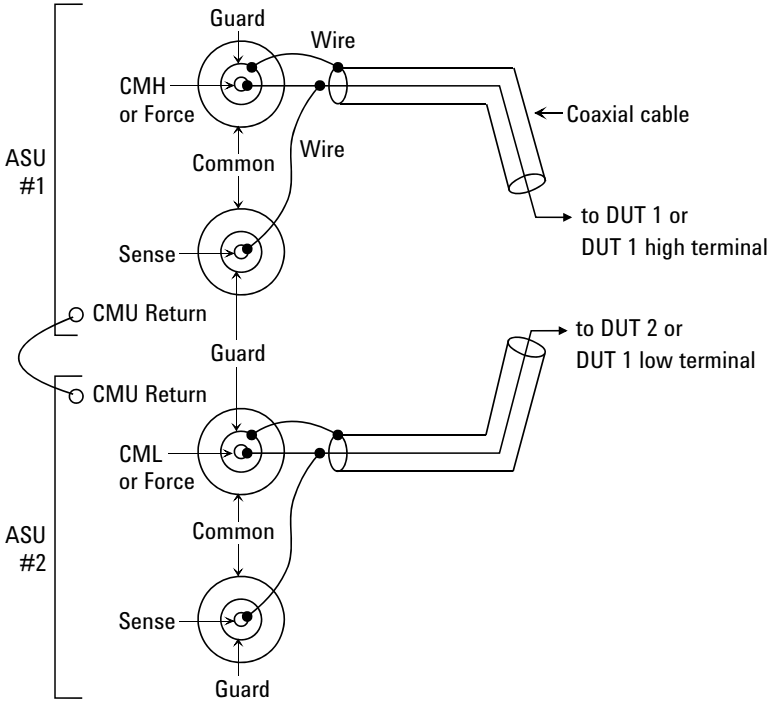
The ASU outputs should be connected to the DUT by using coaxial cables and wires as shown above.

When a SMU is used for the measurements, the Kelvin paths will work as same as Table 3-8.

When a four-terminal pair (4TP) instrument is used, the sense lines can be ignored. And a Kelvin path is used for the high signal, and the other one is used for the low signal. For the accurate impedance measurements, a wire must be connected between the ASU#1 CMU Return and the ASU#2 CMU Return.

If the 4TP instrument is not used, you can ignore the CMH, CML, CMU Return, and the DUT1 high and low terminals.

Figure 3-17 **ASU Output non-Kelvin Connection**



The ASU inputs can be connected to the instruments by using a control cable, a triaxial cable, and two coaxial cables. The cables can be connected to the ASU inside the shielding box through the 16495K plate.

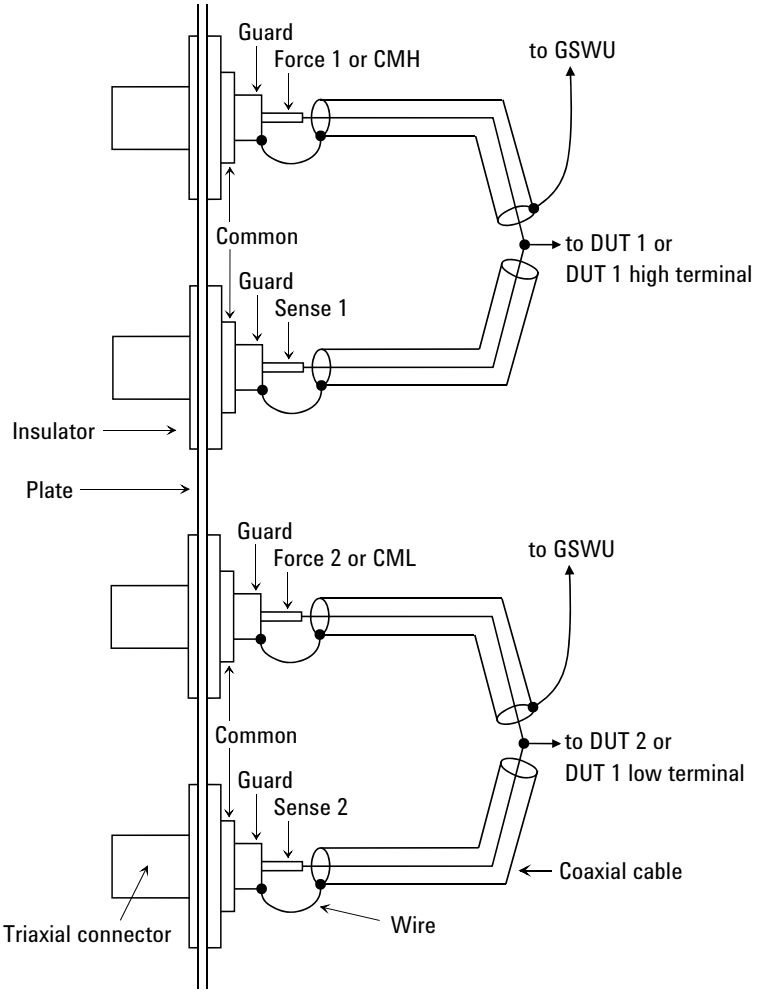
The ASU outputs should be connected to the DUT by using coaxial cables and wires as shown above.

When a SMU is used for the measurements, the Kelvin paths/force lines will work as same as Table 3-8. Then the sense line is not extended to the DUT.

When a four-terminal pair (4TP) instrument is used, the sense lines can be ignored. And a force line is used for the high signal, and the other one is used for the low signal. For the accurate impedance measurements, a wire must be connected between the ASU#1 CMU Return and the ASU#2 CMU Return.

If the 4TP instrument is not used, you can ignore the CMH, CML, CMU Return, and the DUT1 high and low terminals shown above.

Figure 3-18 **SCUU Output Kelvin Connection (Remote Sensing)**

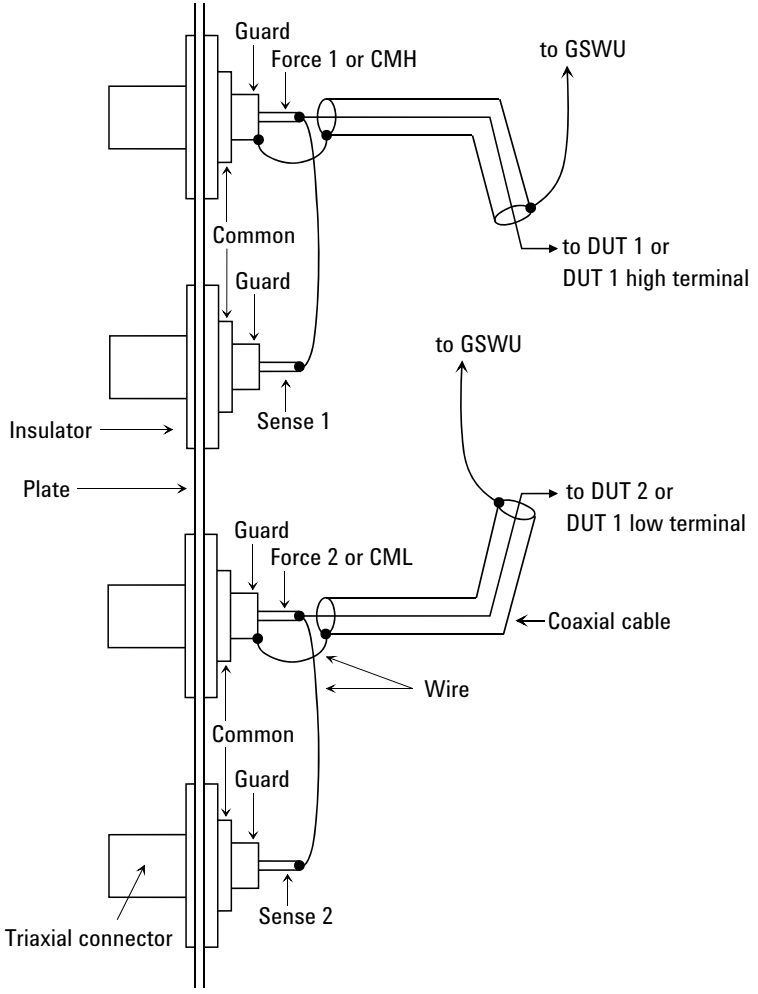


The SCUU should be connected to the DUT by using coaxial cables and wires as shown above. Also the SCUU should be connected to the GSWU inside the shielding box by using a control cable through the 16495K plate.

When a SMU is used for the measurements, the Kelvin paths will work as same as Table 3-8.

When the MFCMU is used, the sense lines can be ignored. And a Kelvin path is used for the CMU high, and the other one is used for the CMU low. For the accurate impedance measurements, wires must be connected to the GSWU from the CMH guard and the CML guard as near as possible to the DUT.

Figure 3-19 **SCUU Output non-Kelvin Connection**



The SCUU should be connected to the DUT by using coaxial cables and wires as shown above. Also the SCUU should be connected to the GSWU inside the shielding box by using a control cable through the 16495K plate.

When a SMU is used for the measurements, the Kelvin paths/force lines will work as same as Table 3-8. Then the sense line is not extended to the DUT.

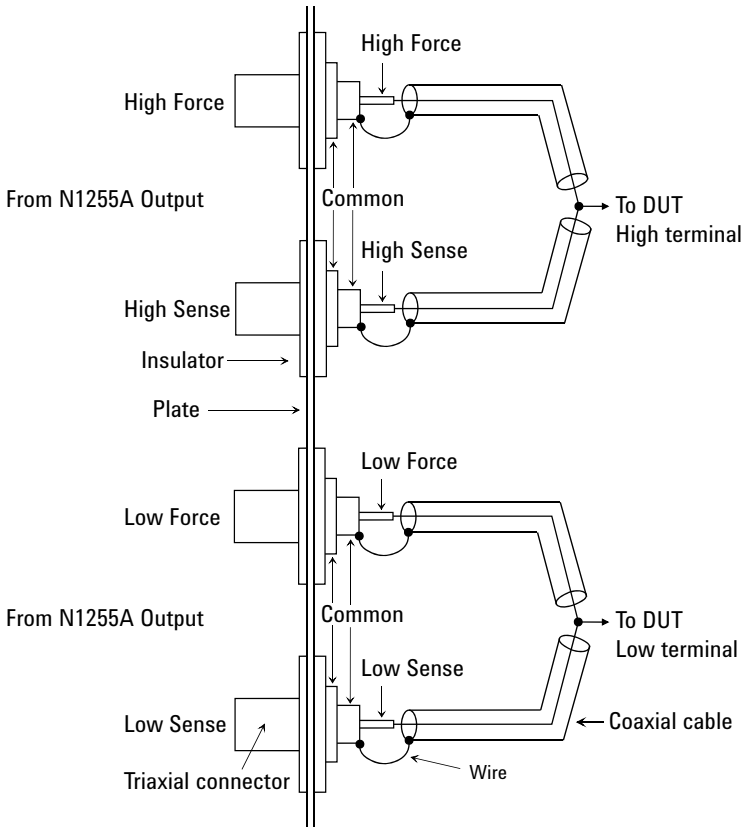
When the MFCMU is used, the sense lines can be ignored. And a force line is used for the CMU high signal, and the other one is used for the CMU low signal. For the accurate impedance measurements, wires must be connected to the GSWU from the CMH guard and the CML guard as near as possible to the DUT.

To Connect MCSMU Output

The MCSMU output connection example is shown in Figure 3-20.

For the connection of the MCSMU, the N1255A connection box is required. See "To Connect MCSMU Connection Box" on page 3-26 to connect the MCSMU to the N1255A Input terminals. To connect the N1255A Output terminals to the connectors as shown in Figure 3-20, use the 16494A triaxial cable.

Figure 3-20 **MCSMU Output Connection**



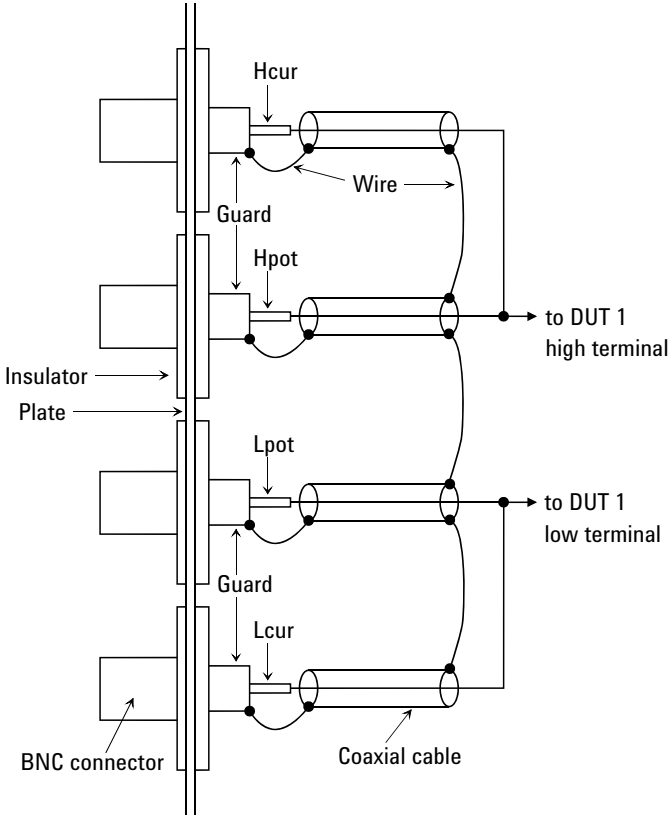
The High Force/High Sense/Low Force/Low Sense lines should be connected to the DUT as shown above. Wiring shown in "To Connect SMU Output" on page 3-35 can be used. To simplify the connections, omit the wiring of the Common.

For the non-Kelvin connection, use the High Force and the Low Force only. Omit the wiring of the High Sense and the Low Sense.

To Connect MFCMU Output

The MFCMU output connection example is shown in Figure 3-21. This connection is for the MFCMU without the SCUU. Then Keysight N1300A-001/002 CMU cable should be used for the connection between the MFCMU and the connectors you mount. It is ok to leave open the ground wire extended from the CMU cable.

Figure 3-21 MFCMU Output Connection



The Hcur/Hpot/Lcur/Lpot lines should be connected to the DUT as shown above.

Use a 50 Ω coaxial cable (Keysight part number: 8120-0367) for the Hcur/Hpot/Lcur/Lpot lines connection. Use a wire for the guard connection.

Connecting Measurement Devices

This section describes how to connect device under test (DUT) to the 16442B test fixture (B1500A-A5F), and how to connect cables to the connector plate.

If you use a wafer prober, see wafer prober manuals.

Note that you must set the module output off when connecting or disconnecting DUTs. If not, the DUTs may be damaged.

To set the module output off, press the **Stop** key.

This section has the following descriptions:

- "Using Test Fixture"
- "Using Connector Plate"

NOTE

Kelvin connection and non-Kelvin connection

To make the Kelvin connection (remote sensing), use both Force and Sense terminals. Connecting the Force and Sense lines together at the terminal of the DUT (device under test) minimizes the measurement error caused by the residual resistance of the connection cables. The Kelvin connection is effective for the low resistance measurement and the high current measurement.

If you want to simplify the cable connections, open the Sense terminals and use the Force terminals only. This is the non-Kelvin connection. The Force terminals can be used to force and measure dc voltage or current.

Using Test Fixture

1. Press the **Stop** key to set the output off.
2. Select a proper socket module for your DUT, then set the socket module on the test fixture.
3. Mount your DUT on the socket module.
4. Connect between the socket module and the test fixture by using the proper test leads.
5. Close the fixture cover.

   To force more than ± 42 V, close the fixture cover. Otherwise, the interlock function will stop Keysight B1500A output.

To connect between the socket module and the test fixture, you can use test leads that have the following terminals:

- Miniature banana-to-miniature banana
- Miniature banana-to-pin plug
- Miniature banana-to-miniature clip

WARNING **Set the instrument output off before connecting or disconnecting test leads.**

Press the front panel Stop key to set the output off. And confirm that the front panel High Voltage indicator is not lit.

WARNING **Make sure that the fixture cover is closed properly before starting measurement. Do not perform the measurement when a test lead is protruding from the test fixture and the cover.**

CAUTION Do not touch the terminals of the test leads. Oil, perspiration, and dirt prevent good electrical contact, deteriorate insulation, and degrade measurement accuracy.

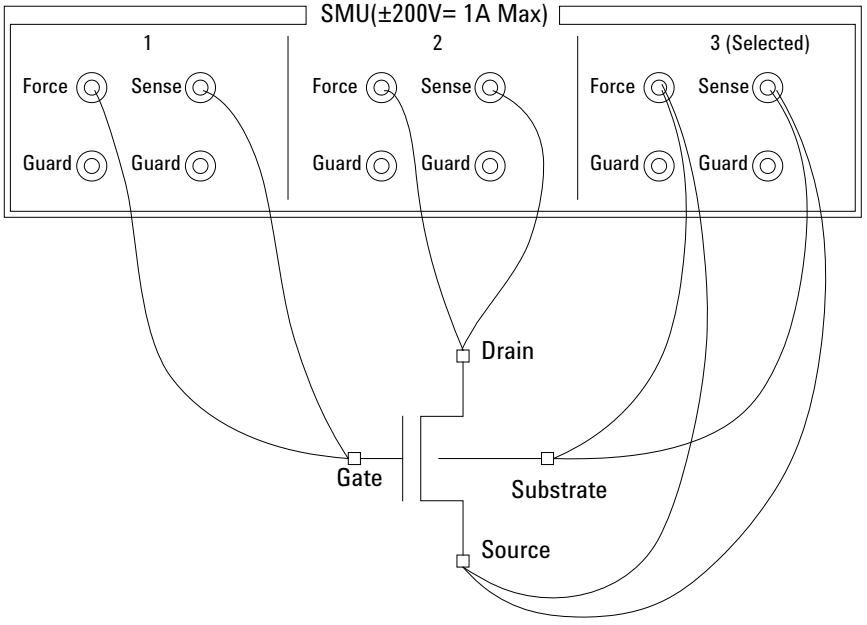
WARNING **To prevent electrical shock and DUT damage, do not connect or disconnect the DUT while the instrument is applying voltage or current.**

When you touch the DUT after measurement, devise a countermeasure of residual charge and heat to prevent electrical shock and burn. Use glove and any tool. Also have enough time for discharge and radiation.

Connections for High Current Measurements

When you force or measure a large current, you may want to use a Kelvin connection (4-wire, remote sensing) to eliminate the residual resistance effects of test leads and contacts. For example, you can use the following connections as Kelvin connections on the test fixture.

Examples: Kelvin Connection



To cancel the effects of the residual resistance, test leads must be connected as close as possible to the DUT.

Using Connector Plate

This section provides the information useful for connecting cables and probing needles to a connector plate.

- "To Reduce Leakage Current"
- "To Measure Low Resistance"

To Reduce Leakage Current

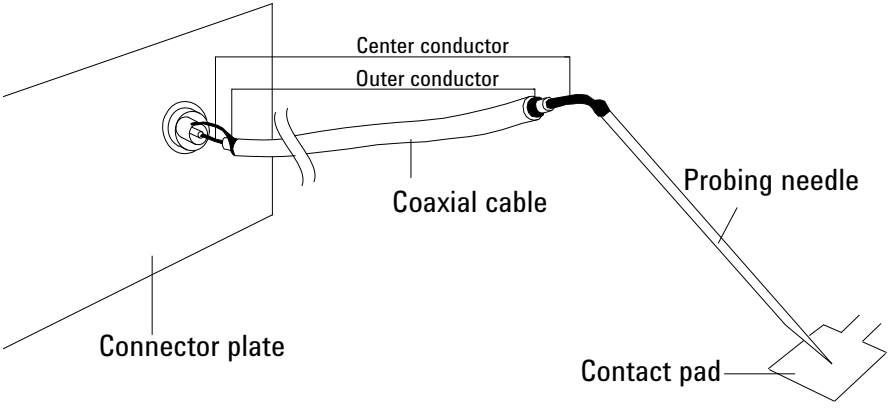
To reduce the leakage current caused by connection cables, the guard technique is effective. Connect the probing needles to the terminals of the connector plate by using coaxial cables as shown below:

1. At end of cable, connect coaxial center conductor to force terminal of connector plate, and connect coaxial outer conductor to guard terminal of connector plate.
2. At another end, connect coaxial center conductor to tail of the probing needle. Never connect the outer conductor at this cable end.

   Extend the outer conductor as close as possible to the probing needle.

Example

The following example connection can be used to reduce the leakage current. Extend the outer conductor as close as possible to the probing needle. This also reduces the induced noise.



WARNING

For safety, prepare and attach a shield cover to the connector plate to avoid touching the joints on the wiring side of connectors. And ground the cover.

Wrap an insulator around the naked conductors of coaxial cable to avoid touching it.

WARNING **To prevent electrical shock and DUT damage, do not connect or disconnect the DUT while the instrument is applying voltage or current.**

When you touch the DUT after measurement, devise a countermeasure of residual charge and heat to prevent electrical shock and burn. Use glove and any tool. Also have enough time for discharge and radiation.

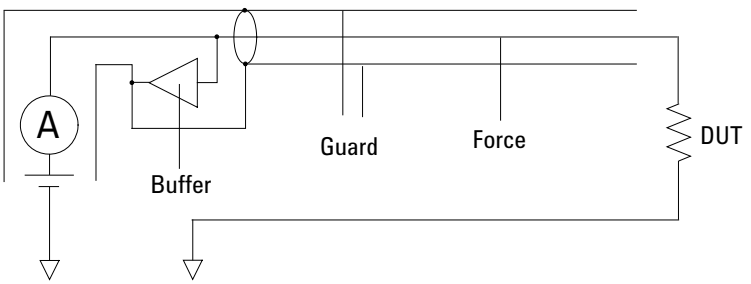
WARNING **Do not touch the guard terminal with bare hands because you may be shocked by high voltage. The potential of the guard terminal is equal to the output voltage.**

CAUTION Never connect the guard terminal to any other output, including circuit common, frame ground, or the terminals of any other measurement resource. Doing so may damage it.

Guarding

Guarding reduces the leakage current between the measurement points and instrument. This is important when you measure low current.

The following figure shows the theory of guarding. The buffer amplifier (×1) keeps the potential of the guard conductor at the same potential as the force conductor, so current does not flow between the force and guard conductors. Therefore, the current measured by SMU is same as current at measurement point because no current is leaked.



To Measure Low Resistance

When you measure a low resistance, high current flows through the DUT. This high current increases the measurement error caused by the residual resistance of cables. To cancel the effect of this resistance, you can use Kelvin connections (4-wire, remote sensing), which means the force and sense lines are extended separately to the DUT.

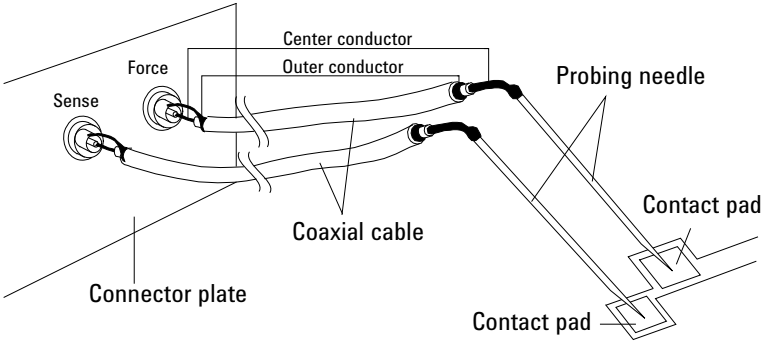
Connect the probing needles to the terminals of the connector plate by using test leads or coaxial cables. Following instruction uses the coaxial cables:

1. At end of cable, connect coaxial center conductor to force terminal of connector plate, and connect coaxial outer conductor to guard terminal of connector plate.
2. At another end, connect coaxial center conductor to tail of the probing needle. Never connect the outer conductor at this cable end.

   Extend the outer conductor as close as possible to the probing needle.
3. Repeat 1 and 2 for the sense terminal of connector plate.
4. Contact the probing needles from force and sense terminals as close as possible to the DUT.

Example

The following example connection can be used to measure low resistance. The sense line is extended to the probing pad, and contacts the force line through the pad, so the voltage drop due to the residual resistance caused by cables and test leads is canceled. To reduce the leakage current, use coaxial cables.



WARNING

For safety, prepare and attach a shield cover to the connector plate to avoid touching the joints on the wiring side of connectors. And ground the cover.

Wrap an insulator around the naked conductors of coaxial cable to avoid touching it.

WARNING

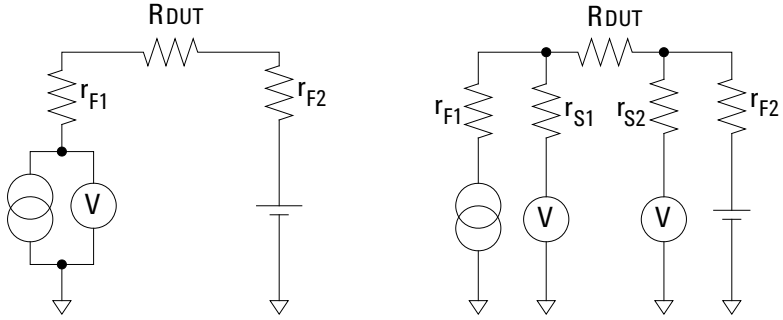
To prevent electrical shock and DUT damage, do not connect or disconnect the DUT while the instrument is applying voltage or current.

When you touch the DUT after measurement, devise a countermeasure of residual charge and heat to prevent electrical shock and burn. Use glove and any tool. Also have enough time for discharge and radiation.

Kelvin Connection (Remote Sensing)

Kelvin connections give good measurement results when you force high-current. The following figure shows the equivalent circuits for Kelvin and non-Kelvin connections.

- For the non-Kelvin connection, the voltmeter measures the voltage drop of resistances r_{F1}, R_{DUT}, and r_{F2}.
- For the Kelvin connection, the voltmeter measures the voltage drop of resistance R_{DUT} only. The impedance of the voltmeter is very high, so the voltage drop of resistances r_{S1} and r_{S2} can be ignored.



(a) non-Kelvin connection (b) Kelvin connection

The Kelvin connection is effective even when forcing voltage. The voltage drop due to the residual resistance of the force line wiring is fed back to the voltage source via a comparator in the sense line. The input impedance of comparator is high, and current flow into the sense line is very low. So output error is not significant if the sense line wiring has a residual resistance of 10 Ω or less. Therefore, the specified voltage appears at the sense point (point where sense line contacts force line)

Capacitance Compensation When Using Switching Matrix

When the capacitance/conductance measurement is performed through Keysight B2200A/B2201A/E5250A switching matrix, Keysight B1500A measures the capacitance/ conductance of the path including a DUT (device under test), matrix switches, extension cables and so on. So, the data measured by the B1500A is far from the DUT's capacitance/conductance.

Keysight EasyEXPERT provides the functions used to compensate the data measured in the environments described in "Required Conditions" on page 3-51. This section explains how to perform compensation.

- "Required Conditions"
- "To Create Compensation Data File"

NOTE

Corrected data by the function is not guaranteed. But typical data (supplemental data) is as follows.

Capacitance measurement accuracy (typical): ±1 % ±0.5 pF

This typical data is for the following measurement conditions:

Measurement frequency: 1 kHz to 5 MHz

Measurement range: Maximum 1000 pF

Measurement terminal: At the end of Keysight 16494A/B/C cable connected to the switch module output terminals.

The typical data does not apply to anything extended from the 16494A/B/C cable. The conditions described in "Required Conditions" on page 3-51 must be satisfied.

Required Conditions

The following conditions must be satisfied to use the capacitance compensation function. For the instrument connections, see Figure 3-22.

- Setting of the MFCMU
  - Range of the measurement frequency: 1 kHz to 5 MHz
  - Measurement function: Cp-G, Cp-D, Cs-Rs, or Z-Th. There is no limitation.
  - Calibration

    Perform the MFCMU open calibration at the end of the measurement paths in front of the switching matrix inputs. If you also perform the short calibration (optional), prepare the BNC thru adapter (Keysight part number 1250-0080, 1 ea.).
  - Total cable length of both Hc-Hp side and Lc-Lp side must be the same.
- Switching matrix input ports

  Use Keysight N1300A CMU cable to connect the MFCMU. The BNC-T adapters (2 ea., Keysight part number 1250-2405 for each) are required to connect between the Hc and Hp terminals and between the Lc and Lp terminals. Connect the Hc-Hp cable and the Lc-Lp cable as follows. It is ok to leave open the ground wire extended from the CMU cable.

  Hc-Hp: Input 13 (B2200A/B2201A) or AUX INPUT CV1 (E5250A)

  Lc-Lp: Input 14 (B2200A/B2201A) or AUX INPUT CV2 (E5250A)
- Switching matrix output terminals

  Use the Keysight 16494A triaxial cable to extend the outputs to the connector plate or the Keysight B2220A probe card interface (only for B2200A/B2201A). For the Kelvin connection, use the Keysight 16494B/C Kelvin triaxial cable.
- Ahead of the connector plate

  Recommended cable: Keysight part number 8121-1191 Triaxial cable

  You can also use another type of triaxial cable, coaxial cable, or combination of these.

  To approximate the capacitance/conductance of the DUT, you need to obtain the appropriate compensation coefficients for your measurement environment, and create your compensation data file. See Figure 3-22.

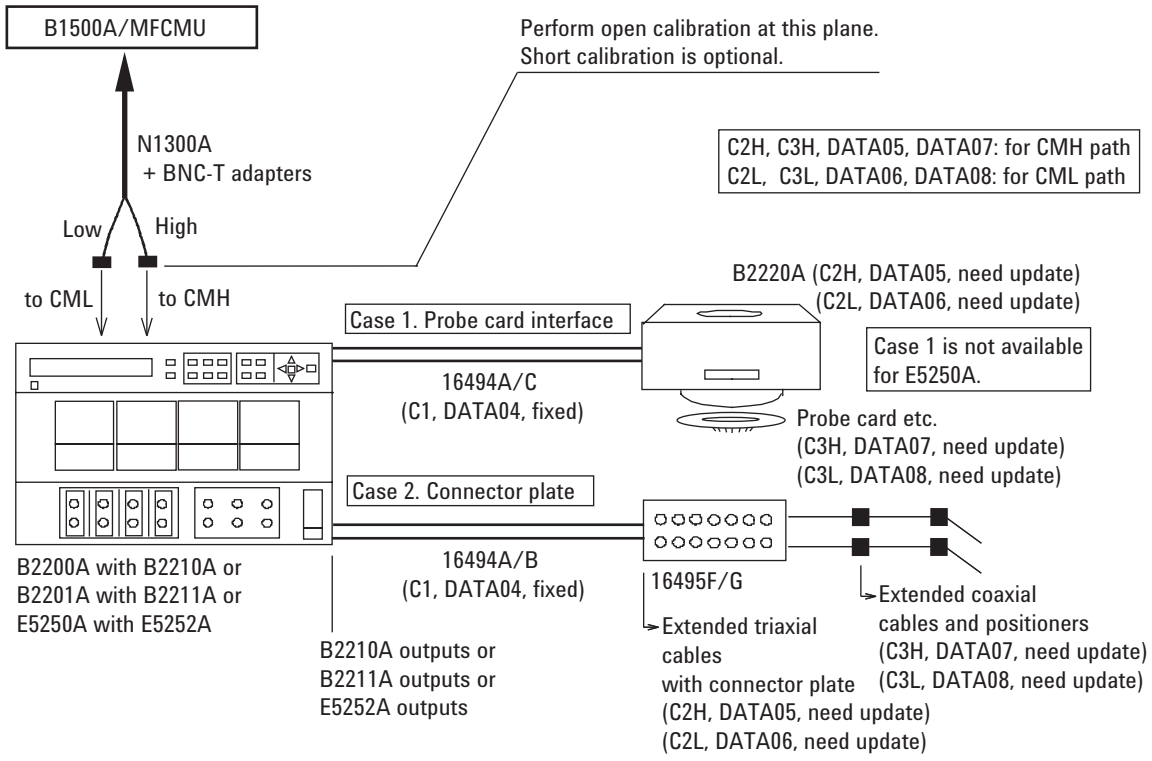
In Figure 3-22, C1 (DATA04), C2H (DATA05), C2L (DATA06), C3H (DATA07), C3L (DATA08) are the compensation coefficients defined in the compensation data file. where, CxH is for the path connected to the MFCMU Hc-Hp terminal, and CxL is for the path connected to the MFCMU Lc-Lp terminal.

When Keysight B2220A probe card interface is used, obtain the coefficients for C3x, and create your compensation data file. In this case, probe card will be used for the C3x path.

When the connector plate is used, obtain the coefficients for C2x and C3x, and create your compensation data file. In this case, triaxial cable with connector plate will be used for the C2x path. And coaxial cable with positioner will be used for the C3x path.

For obtaining the compensation coefficients and creating the compensation data file, see "To Create Compensation Data File" on page 3-53.

Figure 3-22 Extension Cables and Compensation Coefficients



To Create Compensation Data File

This section explains how to create the compensation data file. To perform the capacitance compensation, enter the file name of the compensation data file to the User Compensation Data File field of the Extended Configuration dialog box opened from the Switching Matrix tab screen of the Configuration window.

1. Create a text file (e.g. C:\temp\c_data.txt) that contains the information as shown below.

   - For B2200A/B2201A:

```
#
# Compensation data file for B2210A/Cable connection/3m triax cable
#
#
# MB          Mother Board
# MH          Matrix Path High
# ML          Matrix Path Low
# C1          Triax Cable
# C2H         Probe card I/F or User Triax cable High
# C2L         Probe card I/F or User Triax cable Low
# C3H         Probe card or User Coax cable High
# C3L         Probe card or User Coax cable Low
#
format version 1.0
B2210A
CABLE
#
#     R[Ohm]            L[H]              C[F]
#-------------------------------------------------
MB    0.000000e+00      5.250000e-08      2.940000e-11
MH    2.430000e+00      6.310000e-07      1.930000e-10
ML    2.490000e+00      5.970000e-07      1.920000e-10
C1    6.300000e-01      1.250000e-06      1.600000e-10
C2H   1.007000e-01      4.000000e-07      8.000000e-11
C2L   1.007000e-01      4.000000e-07      8.000000e-11
C3H   1.140000e-01      5.440000e-07      1.300000e-10
C3L   1.140000e-01      5.440000e-07      1.300000e-10
```

   The 15th line specifies the used switch module, B2210A or B2211A.

   The 16th line specifies the DUT interface, PCIF or CABLE. PCIF indicates that Keysight B2220A probe card interface is used. CABLE indicates that the connector plate is used.

   The lines C2H to C3L should be modified for each measurement environment. See Table 3-9. Do not modify the other lines.

NOTE

EasyEXPERT provides the template of the compensation data file for the B2200A/B2201A. See Table 3-11. Select and use the template suitable for your measurement environment.

- For E5250A:

```
# E5250A   C Compensation coefficient data table
#
#   CAUTION : Do not add or delete "REVISION" line and "DATAxx" line.
#             Change the value for R,L,C of DATA05,06,07 or 08.
#
REVISION    A.03.00
#           R [ohm]     L [H]       C [F]
DATA00      74.65E-3    140.00E-9   58.44E-12   # Frame Path 1
DATA01      75.41E-3    90.00E-9    67.13E-12   # Frame Path 2
DATA02      231.41E-3   450.00E-9   178.85E-12  # Card Path High
DATA03      177.56E-3   390.00E-9   135.45E-12  # Card Path Low
DATA04      100.70E-3   400.00E-9   80.00E-12   # Triax Cable      [/m]
DATA05      100.70E-3   400.00E-9   80.00E-12   # User Triax Cbl H [/m]
DATA06      100.70E-3   400.00E-9   80.00E-12   # User Triax Cbl L [/m]
DATA07      114.00E-3   544.00E-9   130.00E-12  # User Coax Cbl H  [/m]
DATA08      114.00E-3   544.00E-9   130.00E-12  # User Coax Cbl L  [/m]
DATA09      0.00E-3     0.00E-9     1.20E-12    # Stray Capacitance
# END of Data
```

The lines DATA05 to DATA08 should be modified for each measurement environment. See Table 3-9. Do not modify the other lines.

Table 3-9 Compensation Coefficients and Modifications

Compensation coefficients	Modifications of data file
C2H (DATA05) C2L (DATA06)	For the connector plate, change the R, L, C values in the lines. The value must be changed to the R, L, C values of the C2H (DATA05) path and the C2L (DATA06) path (triaxial cable with connector plate) shown in Figure 3-22. For Keysight B2220A probe card interface, do not modify the lines.
C3H (DATA07) C3L (DATA08)	Change the R, L, C values in the lines. The value must be changed to the R, L, C values of the C3H (DATA07) path and the C3L (DATA08) path shown in Figure 3-22. For the connector plate, the coaxial cable with positioner will be the appropriate path. For Keysight B2220A probe card interface, the probe card will be the appropriate path.

2. Measure the R, L, C values of the for C2H (DATA05), C2L (DATA06), C3H (DATA07), and C3L (DATA08) by using the MFCMU. See "To obtain compensation coefficients" on page 3-56.

   After the measurements, calculate the per meter value of the R, L, C, and record them into the following table.

Compensation coefficients	**Explanation**		
	R (Ω)	**L (H)**	**C (F)**
C2H (DATA05)			
C2L (DATA06)			
C3H (DATA07)			
C3L (DATA08)			

3. Launch a text editor and open the compensation data file created at step 1.

   Change the R, L, C values of the C2H (DATA05), C2L (DATA06), C3H (DATA07), and C3L (DATA08) lines to the values recorded at step 2. Do not change any other lines.

4. Save the file as your compensation data file (e.g. C:\temp\my_env_1.txt).

   To perform the capacitance compensation, enter the file name of the compensation data file to the User Compensation Data File field of the Extended Configuration dialog box, and execute the measurement.

   Before starting measurement, perform the CMU calibration. For details, see Keysight EasyEXPERT *User's Guide*.

To obtain compensation coefficients

Obtain the compensation coefficients as shown below.

1. Select the measurement frequency (Fmeas) used for the capacitance measurement of a device under test (DUT), and set it to the MFCMU. The coefficients must be measured at the same frequency.
2. Perform the MFCMU open calibration at the measurement terminal. Optionally, perform short calibration if you want.
3. See Table 3-10 and Figure 3-23, and set the MFCMU.
4. Connect the path/cable corresponding to C3H (DATA07) shown in Figure 3-22 to the MFCMU. Then measure and record the R, L, and C values.
5. Connect the path/cable corresponding to C3L (DATA08) to the MFCMU. Then measure and record the R, L, and C values.
6. If you use the connector plate, perform the following procedure.
   a. Connect the path/cable corresponding to C2H (DATA05) to the MFCMU. Then measure and record the R, L, and C values.
   b. Connect the path/cable corresponding to C2L (DATA06) to the MFCMU. Then measure and record the R, L, and C values.

Table 3-10 R, L, C Measurement Conditions

Parameter	Frequency	Function	Terminals
R	1 kHz to 5 MHz [a]	–	A and B
L		SERIES	see note [b]
C		PARALLEL	A and C

a. R, L, C of all coefficients must be measured with the same frequency setting.
b. For triaxial cable, connect B to F directly, and measure L between A and E. For coaxial cable, ignore E and F, and connect B to D directly, and measure L between A and C.

Figure 3-23 Compensation Coefficient Measurement Terminals of Extended Cables

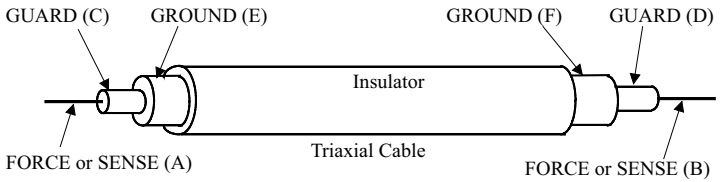


Table 3-11 Template Compensation Data Files for B2200A/B2201A

File name[a]	Measurement environment that template targets			
	Switch module	Cable[b]	DUT interface[c]	Coefficients to be modified
<path>\b2210a\pcif\triax\3m.data	B2210A	16494A-002	B2220A	C3H and C3L
<path>\b2210a\pcif\triax\4m.data		16494A-005		
<path>\b2210a\pcif\kelvin\3m.data		16494C-002		
<path>\b2210a\pcif\kelvin\4m.data		16494C-005		
<path>\b2210a\cable\triax\1_5m.data		16494A-001	16495F/G	C2H, C2L, C3H, and C3L
<path>\b2210a\cable\triax\3m.data		16494A-002		
<path>\b2210a\cable\triax\4m.data		16494A-005		
<path>\b2210a\cable\kelvin\1_5m.data		16494B-001		
<path>\b2210a\cable\kelvin\3m.data		16494B-002		
<path>\b2210a\cable\kelvin\4m.data		16494C-005		
<path>\b2211a\pcif\triax\3m.data	B2211A	16494A-002	B2220A	C3H and C3L
<path>\b2211a\pcif\triax\4m.data		16494A-005		
<path>\b2211a\pcif\kelvin\3m.data		16494C-002		
<path>\b2211a\pcif\kelvin\4m.data		16494C-005		
<path>\b2211a\cable\triax\1_5m.data		16494A-001	16495F/G	C2H, C2L, C3H, and C3L
<path>\b2211a\cable\triax\3m.data		16494A-002		
<path>\b2211a\cable\triax\4m.data		16494A-005		
<path>\b2211a\cable\kelvin\1_5m.data		16494B-001		
<path>\b2211a\cable\kelvin\3m.data		16494B-002		
<path>\b2211a\cable\kelvin\4m.data		16494C-005		

a. <path>: \Program Files\Agilent\B1500\EasyEXPERT\B220xA\ccdata
b. Model number of the cable connected between the switch module and the DUT interface.
c. Keysight B2220A probe card interface or Keysight 16495F/G connector plate.

Maintenance

Maintenance should be performed periodically to keep the instrument in good condition.

Cleaning

Before performing cleaning, turn off the instrument, and disconnect power cable from the rear panel. Use a dry cloth to clean the external case parts.

To prevent electrical shock, do not perform cleaning when the instrument is turned on, and do not use a wet cloth.

Self-test and Diagnostics

This instrument provides the following functions to check the operation. Perform the following functions as necessary. Open the measurement terminals to perform self-test, self-calibration, or diagnostics.

- Self-test
- Self-calibration
- Diagnostics

If problems arise, contact Keysight Technologies. For details, see Keysight EasyEXPERT *User's Guide*.

NOTE

Interlock Open/Close test and High Voltage LED test

Interlock function limits the maximum output voltage to ± 42 V when the measurement terminal is touchable. For safety, this function must be checked before using the B1500A after power on at least once a day by performing the diagnostics.

Calibration

Calibration and adjustments must be performed periodically so that the instruments satisfy the specifications, and keep a good condition. It is recommended to perform the calibration once a year at least. For the calibration and adjustments, contact Keysight Technologies. Trained service personnel will perform the calibration and adjustments. Also see Keysight EasyEXPERT *User's Guide*.

About Plug-in Modules

This section describes the following notices about plug-in modules.

- "Module Type and Locations"
- "To Interconnect SPGUs"
- "To Interconnect WGFMUs"
- "About Module Installation"

Module Type and Locations

Module locations when the B1500A is shipped from the factory are shown in Table 3-12. This table shows the relative locations by the module types.

If the SPGUs are installed, the SPGUs must be installed in the slots from the slot number 1. And if the SPGU and the WGFMU are not installed and the HPSMUs are installed, the HPSMUs must be installed in the slots from the slot number 1. Then the same type of modules must be installed in the contiguous slots.

For example, if the module configuration is two HPSMU, two MPSMU, and one CMU, the B1500A will be shipped with the HPSMUs of the slots 1 to 4, the MPSMUs of the slots 5 to 6, the CMU of the slot 7, and the blank panels of the slots 8 to 10.

Table 3-12 Module Installation Rule

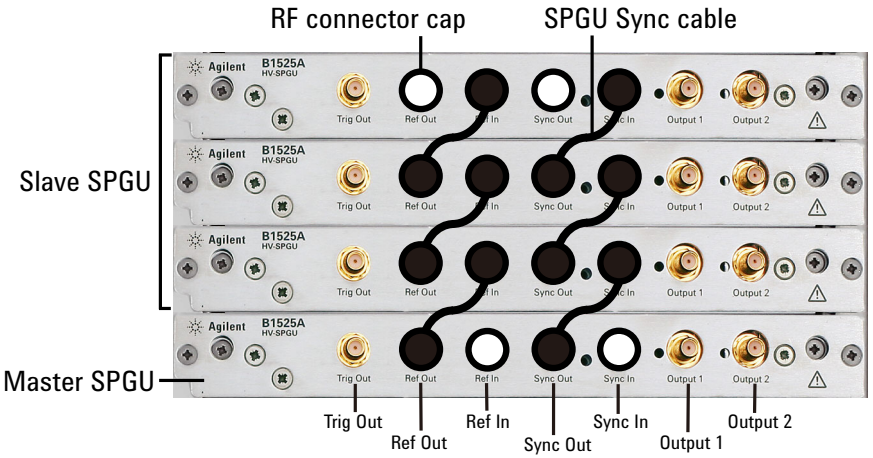
Slot Number and Location		Module Type
10 : : : : : : : : : 1	top : : : : : : : : : : :	B1514A Medium Current SMU (MCSMU)
		B1520A Multi Frequency CMU
		B1511A Medium Power SMU (MPSMU)
		B1511B Medium Power SMU (MPSMU)
		B1517A High Resolution SMU (HRSMU)
		B1510A High Power SMU (HPSMU)
		B1530A WGFMU
		B1525A High Voltage SPGU
0	bottom	GNDU/ADC (always installed)

To Interconnect SPGUs

If multiple SPGUs have been installed, connect the SPGUs by using the following parts furnished with the SPGU. See Figure 3-24.

- SPGU Sync cable, 16493Q-001, (number of SPGUs -1)×2 ea.
- RF connector cap, 1253-7431, 4 ea.

Figure 3-24 **SPGU Module Connection Example, Four Modules**



If multiple SPGUs have been installed, connect the SPGUs as shown in Figure 3-24. This connection makes it possible to perform the synchronous output by the multiple SPGU channels. In this figure, the master SPGU is the module which outputs the reference signal and the slave SPGUs are the modules which follow to the reference signal.

Connect the RF connector cap to the Ref In and Sync In connectors on the master SPGU and the Ref Out and Sync Out connectors on the last slave SPGU.

The Trig Out terminal must be connected to the trigger input terminal of the external equipment to make the synchronized operation of it.

CAUTION Connect the Ref Out/In, Sync Out/In, and Trig Out terminals to the specified terminal properly. Connecting to the other terminal may result in damage to the SPGU.

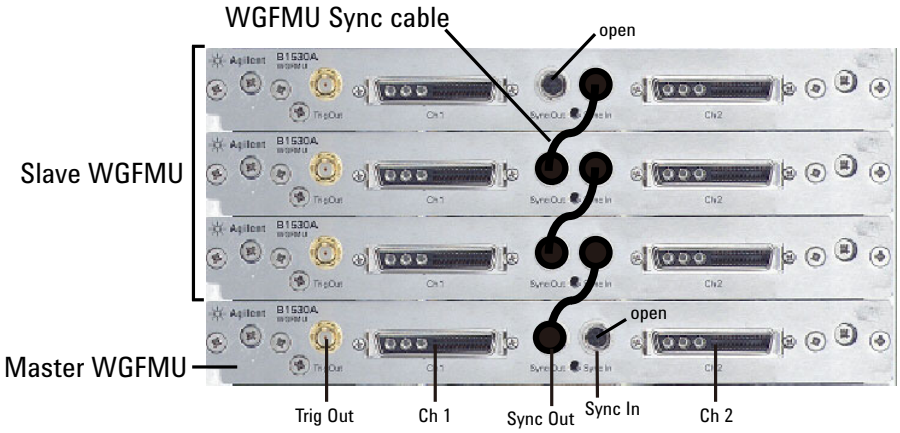
NOTE The B1500A does not support the synchronized operation between SPGU and WGFMU.

To Interconnect WGFMUs

If multiple WGFMUs have been installed, connect the WGFMUs by using the following cable furnished with the WGFMU. See Figure 3-25.

- WGFMU Sync cable, 16493R-803, number of WGFMUs - 1 ea.

Figure 3-25 **WGFMU Module Connection Example, Four Modules**



If multiple WGFMUs have been installed, connect the WGFMUs as shown in Figure 3-25. This connection makes it possible to perform the synchronous output by the multiple WGFMU channels. In this figure, the master WGFMU is the module which outputs the reference signal and the slave WGFMUs are the modules which follow to the reference signal.

Open the Sync In connector on the master WGFMU and the Sync Out connector on the last slave WGFMU.

The Trig Out terminal must be connected to the trigger input terminal of the external equipment to make the synchronized operation of it.

CAUTION Connect the Sync Out/In, and Trig Out terminals to the specified terminal properly. Connecting to the other terminal may result in damage to the WGFMU.

NOTE The B1500A does not support the synchronized operation between SPGU and WGFMU.

About Module Installation

Module installation must be carried out at a Keysight Technologies service center. Contact Keysight Technologies for the module installation. Then send the following equipment and accessories to Keysight Technologies.

- B1500A
- Plug-in modules to be installed
- ASU, for installing the exclusive SMU or retrofitting ASU only
- Connection cable between ASU and SMU, for installing the exclusive SMU or retrofitting ASU only
- RSU, for installing WGFMU
- Connection cable between RSU and WGFMU, for installing WGFMU

For returning ASU or RSU, do not forget to notify the combination of the unit, connection cable, and module channel.

WARNING **To prevent electrical shock, turn the instrument off and remove the power cable before removing the connection cables.**

NOTE About B1500A which supports SPGU and WGFMU

SPGU and WGFMU are supported by the B1500A serial numbered JP40N*xxxxx* and later. The other B1500A needs the mainframe upgrade to support the module. Contact Keysight Technologies to upgrade the B1500A.

NOTE Module locations after servicing

After the module installation, upgrade, and so on, the B1500A will be returned with the module configuration decided by the rule shown in Table 3-12. If you want to change the module locations, consult the service personnel before servicing.

4 Specifications

KEYSIGHT TECHNOLOGIES

This chapter describes the specifications and supplemental characteristics for Keysight B1500A Semiconductor Device Analyzer and its associated modules.

The specifications are the standards against which the B1500A and its associated modules are tested. When the B1500A and any of its associated modules are shipped from the factory, they meet the specifications. The “supplemental” information and “typical” entries in the following specifications are not warranted, but provide useful information about the functions and performance of the instrument.

This chapter contains the following sections.

- “Hardware”
  - “Specification Conditions”
  - “Ground Unit (GNDU)”
  - “MPSMU/HRSMU”
  - “ASU”
  - “HPSMU”
  - “MCSMU”
  - “SMU Common Specifications”
  - “SMU Supplemental Characteristics”
  - “MFCMU”
  - “SCUU/GSWU”
  - “HV-SPGU”
  - “WGFMU/RSU”
- “EasyEXPERT Software”
- “Furnished Software”
- “General Specifications”

Hardware

Specification Conditions

The measurement and output accuracy are specified at the rear panel connector terminals when referenced to the Zero Check terminal. The B1530A WGFMU measurement and output accuracy are specified at the output terminal of the RSU. Accuracy is specified under the following conditions:

1. Temperature: 23 °C ± 5 °C
2. Humidity: 20 % to 60 %
3. After 40 minutes warm-up followed by self-calibration
4. Ambient temperature change less than ± 1 °C after self-calibration execution, not applicable for MFCMU and WGFMU
5. Measurement made within one hour after self-calibration execution, not applicable for MFCMU and WGFMU
6. Calibration period: 1 year
7. SMU integration time setting:

   1 PLC (1 nA to 1 A range, voltage range)

   20 PLC (100 pA range)

   50 PLC (1 pA to 10 pA range)

   Averaging of high speed ADC: 128 samples per 1 PLC
8. SMU filter: ON for HPSMU, MPSMU, and HRSMU
9. SMU measurement terminal connection: Kelvin connection
10. WGFMU load capacitance: 25 pF or less

NOTE Keysight Technologies is responsible for removing, installing, and replacing the B1500A modules. Contact your nearest Keysight Technologies to install and calibrate the B1500A modules.

Supported Plug-in Modules

The B1500A supports ten slots for the following plug-in modules.

B1510A High power source/monitor unit (HPSMU).

- Slots occupied: 2
- Range up to 200 V/1 A with 4-quadrant operation
- Minimum measurement resolution 10 fA/2 μV
- Spot, sweep, and more measurement capabilities
- Sampling (time domain) measurement from 100 μs
- Pulse measurement from 500 μs pulse width
- Accurate Quasi-Static Capacitance Voltage (QSCV) measurement with leakage current compensation

B1511B Medium power source/monitor unit (MPSMU).

- Slots occupied: 1
- Range up to 100 V/0.1 A with 4-quadrant operation
- Minimum measurement resolution 10 fA/0.5 μV
- Optional ASU (atto-sense and switch unit) for 100 aA resolution and IV/CV switching capability
- Spot, sweep, and more measurement capabilities
- Sampling (time domain) measurement from 100 μs
- Pulse measurement from 500 μs pulse width
- Accurate Quasi-Static Capacitance Voltage (QSCV) measurement with leakage current compensation

B1517A High resolution source/monitor unit (HRSMU).

- Slots occupied: 1
- Range up to 100 V/0.1 A with 4-quadrant operation
- Minimum measurement resolution 1 fA/0.5 μV
- Optional ASU (atto-sense and switch unit) for 100 aA resolution and IV/CV switching capability

- Spot, sweep, and more measurement capabilities
- Sampling (time domain) measurement from 100 μs
- Pulse measurement from 500 μs pulse width
- Accurate Quasi-Static Capacitance Voltage (QSCV) measurement with leakage current compensation

B1514A Medium current source/monitor unit (MCSMU).

- Slots occupied: 1
- Range up to 30 V/1 A pulsed (0.1 A DC) with 4-quadrant operation
- Pulse measurement from 50 μs pulse width with 2 μs resolution
- Oscilloscope view for voltage/current waveform monitoring
- Minimum measurement resolution 10 pA/0.2 μV

B1520A Multi-frequency capacitance measurement unit (MFCMU).

- Slots occupied: 1
- AC impedance measurement (C-V, C-f, C-t)
- 1 kHz to 5 MHz frequency range with minimum 1 mHz frequency resolution
- 25 V built-in DC bias and 100 V DC bias with SMU and SCUU (SMU CMU Unify Unit)
- Easy and fast yet accurate IV and CV automated connection change by SCUU

B1525A High voltage semiconductor pulse generator unit (HV-SPGU).

- Slots occupied: 1
- High voltage output up to ± 40 V applicable for non-volatile memory testing
- Two-level and three-level pulse capability by single channel
- Flexible arbitrary waveform generation with 10 ns resolution (arbitrary linear waveform generation function)
- Two channels per module

B1530A Waveform generator / fast measurement unit (WGFMU).

- Slots occupied: 1

- Ultra-fast IV measurement capability for the pulsed IV and transient IV such as NBTI/PBTI, RTN, etc.
- Waveform generation with 10 ns programmable resolution
- Simultaneous high-speed IV measurement capability (200 MSa/s, 5 ns sampling rate)
- 10 V peak-to-peak output
- No load line effect accurate pulsed IV measurement by dynamic SMU technology

Maximum Module Configuration

The B1500A can contain any combination of the following module. Then the total power consumption of all SMU modules cannot exceed 84 W.

- Up to 10 MPSMU
- Up to 10 HRSMU
- Up to 4 HPSMU
- Up to 4 MCSMU
- One MFCMU
- Up to 5 HV-SPGU
- Up to 5 WGFMU

When one or more WGFMU modules are installed in the B1500A mainframe, the following table applies. Multiply the values given below by the number of installed modules of that type and add the products together. The sum of the products must be less than or equal to 59 for the configuration to be permissible.

MPSMU	2
HRSMU	2
HPSMU	14
MCSMU	5
MFCMU	7
HV-SPGU	12
WGFMU	10

Maximum Voltage between Common and Ground

≤ ± 42 V

Ground Unit (GNDU)

The GNDU is furnished standard with the mainframe.

- Output voltage: 0 V ± 100 μV
- Maximum sink current: ± 4.2 A
- Output terminal/connection: Triaxial connector, Kelvin (remote sensing)
- Load capacitance: 1 μF, supplemental characteristics
- Cable resistance: supplemental characteristics

Terminal	Cable resistance
Sense	≤ 10 Ω
Force	< 1 Ω (Is ≤ 1.6 A) < 0.7 Ω (1.6 A < Is ≤ 2.0 A) < 0.35 Ω (2.0 A < Is ≤ 4.2 A) where Is is the current being sunk by the GNDU.

MPSMU/HRSMU

MPSMU: Medium Power Source/Monitor Unit

HRSMU: High Resolution Source/Monitor Unit

- Voltage range, resolution, and accuracy

  See Table 4-1 for high resolution ADC and Table 4-3 for high speed ADC.

- Current range, resolution, and accuracy

  See Table 4-2 for high resolution ADC and Table 4-4 for high speed ADC.

  Specified measurement resolution is limited by fundamental noise limits. Minimum displayed resolution is 1 aA at 1 pA range by 6 digits. Measurements made in the lower ranges can be greatly impacted by vibrations and shocks. These specifications assume an environment free of these factors.

- Power consumption

  Voltage source mode:

Voltage range (V)	Power consumption[a] (W)
0.5	Ic × 20
2	Ic × 20
5	Ic × 20
20	Ic × 20
40	Ic × 40
100	Ic × 100

a. Ic is the current compliance setting.

  Current source mode:

Voltage compliance[a] (V)	Power consumption[b] (W)
Vc ≤ 20	Io × 20
20 < Vc ≤ 40	Io × 40
40 < Vc ≤ 100	Io × 100

a. Vc is the voltage compliance setting.
b. Io is the output current.

Table 4-1 Voltage range, resolution, and accuracy (high resolution ADC)

Range	Force resolution	Measurement resolution	Force accuracy ±(%+mV)[a]	Measurement accuracy ±(%+mV)[a]	Maximum current
±0.5 V	25 μV	0.5 μV	±(0.018 + 0.15)	±(0.01 + 0.12)	100 mA
±2 V	100 μV	2 μV	±(0.018 + 0.4)	±(0.01 + 0.14)	100 mA
±5 V	250 μV	5 μV	±(0.018 + 0.75)	±(0.009 + 0.25)	100 mA
±20 V	1 mV	20 μV	±(0.018 + 3)	±(0.009 + 0.9)	100 mA
±40 V	2 mV	40 μV	±(0.018 + 6)	±(0.01 + 1)	b
±100 V	5 mV	100 μV	±(0.018 + 15)	±(0.012 + 2.5)	

a. ±(% of output/measured value + offset value in mV)
b. 100 mA (Vo ≤ 20 V), 50 mA (20 V < Vo ≤ 40 V), 20 mA (40 V < Vo), Vo is the output voltage.

Table 4-2 Current range, resolution, and accuracy (high resolution ADC)

Range	Force resolution	Measurement resolution	Force accuracy ±(%+A+A)[a]	Measurement accuracy ±(%+A+A)[a]	Maximum voltage
±1 pA[b]	1 fA	0.1 fA	±(0.9+15E-15)	±(0.9+12E-15)	100 V
±10 pA[c]	5 fA	0.4 fA[b] / 1 fA	±(0.46+3E-14+Vo×1E-17)	±(0.46+15E-15+Vo×1E-17)	100 V
±100 pA[c]	5 fA	0.5 fA[b] / 2 fA	±(0.3+1E-13+Vo×1E-16)	±(0.3+3E-14+Vo×1E-16)	100 V
±1 nA	50 fA	10 fA	±(0.1+3E-13+Vo×1E-15)	±(0.1+2E-13+Vo×1E-15)	100 V
±10 nA	500 fA	10 fA	±(0.1+3E-12+Vo×1E-14)	±(0.1+1E-12+Vo×1E-14)	100 V
±100 nA	5 pA	100 fA	±(0.05+3E-11+Vo×1E-13)	±(0.05+2E-11+Vo×1E-13)	100 V
±1 μA	50 pA	1 pA	±(0.05+3E-10+Vo×1E-12)	±(0.05+1E-10+Vo×1E-12)	100 V
±10 μA	500 pA	10 pA	±(0.05+3E-9+Vo×1E-11)	±(0.04+2E-9+Vo×1E-11)	100 V
±100 μA	5 nA	100 pA	±(0.035+15E-9+Vo×1E-10)	±(0.03+3E-9+Vo×1E-10)	100 V
±1 mA	50 nA	1 nA	±(0.04+15E-8+Vo×1E-9)	±(0.03+6E-8+Vo×1E-9)	100 V
±10 mA	500 nA	10 nA	±(0.04+15E-7+Vo×1E-8)	±(0.03+2E-7+Vo×1E-8)	100 V
±100 mA	5 μA	100 nA	±(0.045+15E-6+Vo×1E-7)	±(0.04+6E-6+Vo×1E-7)	d

a. ±(% of output/measured value + fixed offset in A + proportional offset in A), Vo is the output voltage in V.
b. Applicable if Keysight E5288A Atto Sense and Switch Unit (ASU) is used.
c. Not applicable for the MPSMU without ASU.
d. 100 V (Io ≤ 20 mA), 40 V (20 mA < Io ≤ 50 mA), 20 V (50 mA < Io), Io is the output current.

Table 4-3 Voltage range, resolution, and accuracy (high speed ADC)

Range	Force resolution	Measurement resolution	Force accuracy ±(%+mV)[a]	Measurement accuracy ±(%+mV)[a]	Maximum current
±0.5 V	25 μV	25 μV	±(0.018 + 0.15)	±(0.01 + 0.25)	100 mA
±2 V	100 μV	100 μV	±(0.018 + 0.4)	±(0.01 + 0.7)	100 mA
±5 V	250 μV	250 μV	±(0.018 + 0.75)	±(0.01 + 2)	100 mA
±20 V	1 mV	1 mV	±(0.018 + 3)	±(0.01 + 4)	100 mA
±40 V	2 mV	2 mV	±(0.018 + 6)	±(0.015 + 8)	b
±100 V	5 mV	5 mV	±(0.018 + 15)	±(0.02 + 20)	

a. ±(% of output/measured value + offset value in mV)
b. 100 mA (Vo ≤ 20 V), 50 mA (20 V < Vo ≤ 40 V), 20 mA (40 V < Vo), Vo is the output voltage.

Table 4-4 Current range, resolution, and accuracy (high speed ADC)

Range	Force resolution	Measurement resolution	Force accuracy ±(%+A+A)[a]	Measurement accuracy ±(%+A+A)[a]	Maximum voltage
±1 pA[b]	1 fA	0.1 fA	±(0.9+15E-15)	±(1.8+12E-15)	100 V
±10 pA[c]	5 fA	1 fA	±(0.46+3E-14+Vo×1E-17)	±(0.5+15E-15+Vo×1E-17)	100 V
±100 pA[c]	5 fA	5 fA	±(0.3+1E-13+Vo×1E-16)	±(0.5+4E-14+Vo×1E-16)	100 V
±1 nA	50 fA	50 fA	±(0.1+3E-13+Vo×1E-15)	±(0.25+3E-13+Vo×1E-15)	100 V
±10 nA	500 fA	500 fA	±(0.1+3E-12+Vo×1E-14)	±(0.25+2E-12+Vo×1E-14)	100 V
±100 nA	5 pA	5 pA	±(0.05+3E-11+Vo×1E-13)	±(0.1+2E-11+Vo×1E-13)	100 V
±1 μA	50 pA	50 pA	±(0.05+3E-10+Vo×1E-12)	±(0.1+2E-10+Vo×1E-12)	100 V
±10 μA	500 pA	500 pA	±(0.05+3E-9+Vo×1E-11)	±(0.05+2E-9+Vo×1E-11)	100 V
±100 μA	5 nA	5 nA	±(0.035+15E-9+Vo×1E-10)	±(0.05+2E-8+Vo×1E-10)	100 V
±1 mA	50 nA	50 nA	±(0.04+15E-8+Vo×1E-9)	±(0.04+2E-7+Vo×1E-9)	100 V
±10 mA	500 nA	500 nA	±(0.04+15E-7+Vo×1E-8)	±(0.04+2E-6+Vo×1E-8)	100 V
±100 mA	5 μA	5 μA	±(0.045+15E-6+Vo×1E-7)	±(0.1+2E-5+Vo×1E-7)	d

a. ±(% of output/measured value + fixed offset in A + proportional offset in A), Vo is the output voltage in V.
b. Applicable if Keysight E5288A Atto Sense and Switch Unit (ASU) is used.
c. Not applicable for the MPSMU without ASU.
d. 100 V (Io ≤ 20 mA), 40 V (20 mA < Io ≤ 50 mA), 20 V (50 mA < Io), Io is the output current.

ASU

ASU: Atto Sense and Switch Unit

- Maximum voltage, AUX path

  100 V (AUX input to AUX common)

  100 V (AUX input to circuit common)

  42 V (AUX common to circuit common)

- Maximum current, AUX path

  0.5 A (AUX input to Force output)

- Band width (at -3 dB), AUX port

  30 MHz, supplemental characteristics

NOTE Connect ASU to dedicated SMU

The specifications of the ASU are guaranteed while it is connected to the exclusive SMU which is connected together when the calibration is performed. Confirm the serial number of the ASU, and connect it properly.

NOTE Connection path control

Disable source output of the instruments connected to the ASU inputs before controlling the ASU connection path.

HPSMU

HPSMU: High Power Source/Monitor Unit

- Voltage range, resolution, and accuracy

  See Table 4-5 for high resolution ADC and Table 4-7 for high speed ADC.

- Current range, resolution, and accuracy

  See Table 4-6 for high resolution ADC and Table 4-8 for high speed ADC.

  Specified measurement resolution is limited by fundamental noise limits.

- Power consumption

  Voltage source mode:

Voltage range (V)	Power consumption[a] (W)
2	Ic × 20
20	Ic × 20
40	Ic × 40
100	Ic × 100
200	Ic × 200

a. Ic is the current compliance setting.

Current source mode:

Voltage compliance[a] (V)	Power consumption[b] (W)
Vc ≤ 20	Io × 20
20 < Vc ≤ 40	Io × 40
40 < Vc ≤ 100	Io × 100
100 < Vc ≤ 200	Io × 200

a. Vc is the voltage compliance setting.
b. Io is the output current.

Table 4-5 Voltage range, resolution, and accuracy (high resolution ADC)

Range	Force resolution	Measurement resolution	Force accuracy ±(%+mV)[a]	Measurement accuracy ±(%+mV)[a]	Maximum current
±2 V	100 μV	2 μV	±(0.018 + 0.4)	±(0.01 + 0.14)	1 A
±20 V	1 mV	20 μV	±(0.018 + 3)	±(0.009 + 0.9)	1 A
±40 V	2 mV	40 μV	±(0.018 + 6)	±(0.01 + 1)	500 mA
±100 V	5 mV	100 μV	±(0.018 + 15)	±(0.012 + 2.5)	125 mA
±200 V	10 mV	200 μV	±(0.018 + 30)	±(0.014 + 2.8)	50 mA

a. ±(% of output/measured value + offset value in mV)

Table 4-6 Current range, resolution, and accuracy (high resolution ADC)

Range	Force resolution	Measurement resolution	Force accuracy ±(%+A+A)[a]	Measurement accuracy ±(%+A+A)[a]	Maximum voltage
±1 nA	50 fA	10 fA	±(0.1+3E-13+Vo×1E-15)	±(0.1+2E-13+Vo×1E-15)	200 V
±10 nA	500 fA	10 fA	±(0.1+3E-12+Vo×1E-14)	±(0.1+1E-12+Vo×1E-14)	200 V
±100 nA	5 pA	100 fA	±(0.05+3E-11+Vo×1E-13)	±(0.05+2E-11+Vo×1E-13)	200 V
±1 μA	50 pA	1 pA	±(0.05+3E-10+Vo×1E-12)	±(0.05+1E-10+Vo×1E-12)	200 V
±10 μA	500 pA	10 pA	±(0.05+3E-9+Vo×1E-11)	±(0.04+2E-9+Vo×1E-11)	200 V
±100 μA	5 nA	100 pA	±(0.035+15E-9+Vo×1E-10)	±(0.03+3E-9+Vo×1E-10)	200 V
±1 mA	50 nA	1 nA	±(0.04+15E-8+Vo×1E-9)	±(0.03+6E-8+Vo×1E-9)	200 V
±10 mA	500 nA	10 nA	±(0.04+15E-7+Vo×1E-8)	±(0.03+2E-7+Vo×1E-8)	200 V
±100 mA	5 μA	100 nA	±(0.045+15E-6+Vo×1E-7)	±(0.04+6E-6+Vo×1E-7)	b
±1 A	50 μA	1 μA	±(0.4+3E-4+Vo×1E-6)	±(0.4+15E-5+Vo×1E-6)	

a. ±(% of output/measured value + fixed offset in A + proportional offset in A), Vo is the output voltage in V.

b. 200 V (Io ≤ 50 mA), 100 V (50 mA < Io ≤ 125 mA), 40 V (125 mA < Io ≤ 500 mA), 20 V (500 mA < Io ≤ 1 A), Io is the output current.

Table 4-7 Voltage range, resolution, and accuracy (high speed ADC)

Range	Force resolution	Measurement resolution	Force accuracy ±(%+mV)[a]	Measurement accuracy ±(%+mV)[a]	Maximum current
±2 V	100 μV	100 μV	±(0.018 + 0.4)	±(0.01 + 0.7)	1 A
±20 V	1 mV	1 mV	±(0.018 + 3)	±(0.01 + 4)	1 A
±40 V	2 mV	2 mV	±(0.018 + 6)	±(0.015 + 8)	500 mA
±100 V	5 mV	5 mV	±(0.018 + 15)	±(0.02 + 20)	125 mA
±200 V	10 mV	10 mV	±(0.018 + 30)	±(0.035 + 40)	50 mA

a. ±(% of output/measured value + offset value in mV)

Table 4-8 Current range, resolution, and accuracy (high speed ADC)

Range	Force resolution	Measurement resolution	Force accuracy ±(%+A+A)[a]	Measurement accuracy ±(%+A+A)[a]	Maximum voltage
±1 nA	50 fA	50 fA	±(0.1+3E-13+Vo×1E-15)	±(0.25+3E-13+Vo×1E-15)	200 V
±10 nA	500 fA	500 fA	±(0.1+3E-12+Vo×1E-14)	±(0.25+2E-12+Vo×1E-14)	200 V
±100 nA	5 pA	5 pA	±(0.05+3E-11+Vo×1E-13)	±(0.1+2E-11+Vo×1E-13)	200 V
±1 μA	50 pA	50 pA	±(0.05+3E-10+Vo×1E-12)	±(0.1+2E-10+Vo×1E-12)	200 V
±10 μA	500 pA	500 pA	±(0.05+3E-9+Vo×1E-11)	±(0.05+2E-9+Vo×1E-11)	200 V
±100 μA	5 nA	5 nA	±(0.035+15E-9+Vo×1E-10)	±(0.05+2E-8+Vo×1E-10)	200 V
±1 mA	50 nA	50 nA	±(0.04+15E-8+Vo×1E-9)	±(0.04+2E-7+Vo×1E-9)	200 V
±10 mA	500 nA	500 nA	±(0.04+15E-7+Vo×1E-8)	±(0.04+2E-6+Vo×1E-8)	200 V
±100 mA	5 μA	5 μA	±(0.045+15E-6+Vo×1E-7)	±(0.1+2E-5+Vo×1E-7)	b
±1 A	50 μA	50 μA	±(0.4+3E-4+Vo×1E-6)	±(0.5+3E-4+Vo×1E-6)	

a. ±(% of output/measured value + fixed offset in A + proportional offset in A), Vo is the output voltage in V.
b. 200 V (Io ≤ 50 mA), 100 V (50 mA < Io ≤ 125 mA), 40 V (125 mA < Io ≤ 500 mA), 20 V (500 mA < Io ≤ 1 A), Io is the output current.

MCSMU

Medium Current Source/Monitor Unit

- Voltage range, resolution, and accuracy

  See Table 4-9.

- Current range, resolution, and accuracy

  See Table 4-10.

- Power consumption

  Voltage source mode:

Voltage range (V)	Power consumption[a] (W)
0.2	Ic × 40
2	Ic × 40
40	Ic × 40

a. Ic is the current compliance setting.

Current source mode:

Voltage compliance[a] (V)	Power consumption[b] (W)
Vc ≤ 0.2	Io × 40
0.2 < Vc ≤ 2	Io × 40
2 < Vc ≤ 40	Io × 40

a. Vc is the voltage compliance setting.
b. Io is the output current.

Table 4-9 MCSMU voltage range, resolution, and accuracy

Range	Force resolution	Measurement resolution	Force accuracy ±(%+mV)[a]	Measurement accuracy ±(%+mV+mV)[a]	Maximum current
±0.2 V	200 nV	200 nV	±(0.06+0.14)	±(0.06+0.14+Io×0.05)	1 A
±2 V	2 μV	2 μV	±(0.06+0.6)	±(0.06+0.6+Io×0.5)	1 A
±20 V	20 μV	20 μV	±(0.06+3)	±(0.06+3+Io×5)	1 A
±40 V[b]	40 μV	40 μV	±(0.06+3)	±(0.06+3+Io×10)	1 A

a. ±(% of output/measured value + fixed offset + proportional offset), Io is the output current in A.
b. Maximum output voltage is 30 V.

Table 4-10 MCSMU current range, resolution, and accuracy

Range	Force resolution	Measurement resolution	Force accuracy ±(%+A+A)[a]	Measurement accuracy ±(%+A+A)[a]	Maximum voltage
±10 μA	10 pA	10 pA	±(0.06+2E-9+Vo×1E-10)	±(0.06+2E-9+Vo×1E-10)	30 V
±100 μA	100 pA	100 pA	±(0.06+2E-8+Vo×1E-9)	±(0.06+2E-8+Vo×1E-9)	30 V
±1 mA	1 nA	1 nA	±(0.06+2E-7+Vo×1E-8)	±(0.06+2E-7+Vo×1E-8)	30 V
±10 mA	10 nA	10 nA	±(0.06+2E-6+Vo×1E-7)	±(0.06+2E-6+Vo×1E-7)	30 V
±100 mA	100 nA	100 nA	±(0.06+2E-5+Vo×1E-6)	±(0.06+2E-5+Vo×1E-6)	30 V
±1 A[b]	1 μA	1 μA	±(0.4+2E-4+Vo×1E-5)	±(0.4+2E-4+Vo×1E-5)	30 V

a. ±(% of output/measured value + fixed offset + proportional offset), Vo is the output voltage in V.
b. Pulse mode only. The maximum value of the base current during pulsing is ±50 mA.

SMU Common Specifications

- Output terminal/connection

  Dual triaxial connector, Kelvin (remote sensing)

- Voltage/current compliance (limiting)

  The SMU can limit output voltage or current to prevent damaging the device under test.

  - Voltage compliance:

    0 V to ± 100 V (MPSMU, HRSMU)

    0 V to ± 200 V (HPSMU)

    0 V to ± 30 V (MCSMU)

  - Current compliance:

    ± 10 fA to ± 100 mA (HRSMU/MPSMU with ASU)

    ± 100 fA to ± 100 mA (HRSMU)

    ± 1 pA to ± 100 mA (MPSMU)

    ± 1 pA to ± 1 A (HPSMU)

    ± 10 nA to ± 1 A (MCSMU)

  - Compliance accuracy:

    Same as the current or voltage set accuracy.

- Pulsed measurement

  Programmable pulse width, period, and delay:

  For HPSMU, MPSMU, HRSMU

  - Width: 500 μs to 2 s, 100 μs resolution
  - Period: 5 ms to 5 s, 100 μs resolution

    Period ≥ Width+2 ms (when Width ≤ 100 ms)

    Period ≥ Width+10 ms (when Width > 100 ms)
  - Delay: 0 s

For MCSMU

- Width: 10 μs to 100 ms (1 A range), 10 μs to 2 s (10 μA to 100 mA ranges), 2 μs resolution

  Recommended pulse width: ≥ 50 μs (time to reach within 1 % of the final value at resistive load ≥ 50 Ω, 10 V step voltage, and 1 A compliance, supplemental characteristics)

- Period: 5 ms to 5 s, 100 μs resolution
- Pulse duty:

  For 1 A range: ≤ 5 %

  For 10 μA to 100 mA ranges:

  Period ≥ Width+Delay+2 ms (when Width+Delay ≤ 100 ms)

  Period ≥ Width+Delay+10 ms (when Width+Delay > 100 ms)

- Delay: 0 to (Period - Width) s, 2 μs resolution

- About measurement accuracy
  - RF electromagnetic field and SMU measurement accuracy

    Voltage and current measurement accuracy may be affected by RF electromagnetic field of strength over 3 V/m at frequencies 80 MHz to 1 GHz and 1.4 GHz to 2.0 GHz, and 1 V/m at frequencies 2.0 GHz to 2.7 GHz. The extent of this effect depends upon how the instrument is positioned and shielded.

  - Induced RF field noise and SMU measurement accuracy

    Voltage and current measurement accuracy can be affected by induced RF field noise strengths greater than 3Vrms in the frequency range of 150 kHz to 80 MHz. The extent of this effect depends upon how the instrument is positioned and shielded.

SMU Supplemental Characteristics

- Current compliance setting accuracy (for opposite polarity)

  For HPSMU, MPSMU, HRSMU

  ± (setting accuracy + 12 % of range), for 1 pA to 10 nA ranges

  ± (setting accuracy + 2.5 % of range), for 100 nA to 1 A ranges

  For MCSMU

  ± (setting accuracy + 2.5 % of range)

- SMU pulse setting accuracy (fixed measurement range)

  For HPSMU, MPSMU, HRSMU

  Width: ± (0.5 % + 50 μs)

  Period: ± (0.5 % + 100 μs)

  For MCSMU

  Width: ± (0.1 % + 2 μs)

  Period: ± (0.1 % + 100 μs)

- Minimum pulse measurement time

  For HPSMU, MPSMU, HRSMU: 16 μs

  For MCSMU: 2 μs

- Voltage source output resistance (Force line, Non-Kelvin connection)

  0.2 Ω (HPSMU)

  0.3 Ω (MPSMU, HRSMU)

- Voltage measurement input resistance

  For HPSMU, MPSMU, HRSMU: ≥ 10^{13} Ω

  For MCSMU: ≥ 10^{9} Ω

- Current source output resistance

  For HPSMU, MPSMU, HRSMU: ≥ 10^{13} Ω

  For MCSMU: ≥ 10^{9} Ω

- Maximum allowable cable resistance (Kelvin connection)

  For HPSMU, MPSMU, HRSMU: 10 Ω (Sense), 10 Ω (Force, ≤ 100 mA), 1.5 Ω (Force, > 100 mA)

  For MCSMU: 10 Ω (Sense), 1 Ω (Force, between high and low)

- Maximum allowable inductance

  For MCSMU: 3 μH (Force, with low force as shield)

- Maximum load capacitance

  For HPSMU, MPSMU, HRSMU

  1000 pF, for 1 pA to 10 nA ranges

  10 nF, for 100 nA to 10 mA ranges

  100 μF, for 100 mA and 1 A ranges

  For MCSMU

  12 nF, for 10 μA to 10 mA ranges

  100 μF, for 100 mA and 1 A ranges

- Maximum guard capacitance

  900 pF (HPSMU, MPSMU, HRSMU)

  660 pF (HRSMU/MPSMU with ASU)

- Maximum shield capacitance

  5000 pF (HPSMU, MPSMU, HRSMU)

  3500 pF (HRSMU/MPSMU with ASU)

- Noise characteristics

  For HPSMU, MPSMU, HRSMU

  Voltage source: 0.01 % of V range (rms.)

  Current source: 0.1 % of I range (rms.)

  For MCSMU

  Voltage/Current source: 200 mV (0 to peak) max

  Condition: filter ON for HPSMU, MPSMU, and HRSMU

- Overshoot (filter ON)

  For HPSMU, MPSMU, HRSMU

  Voltage source: 0.03 % of V range

  Current source: 1 % of I range

  For MCSMU

  Voltage/Current source: 10 % of range
- Range switching transient noise

  Voltage ranging: 250 mV

  Current ranging: 70 mV

  Condition: filter ON for HPSMU, MPSMU, and HRSMU
- Maximum guard offset voltage

  ± 1 mV (HPSMU)

  ± 3 mV (MPSMU, HRSMU)

  ± 4.2 mV (HRSMU/MPSMU with ASU, Iout ≤ 100 μA)
- Maximum slew rate

  0.2 V/μs (HPSMU, MPSMU, HRSMU)

  1 V/μs (MCSMU)
- Maximum DC floating voltage

  ± 200 V DC between low force and common (MCSMU)

MFCMU

MFCMU: Multi Frequency Capacitance Measurement Unit

- Measurement functions
  - Measurement parameters: Cp-G, Cp-D, Cp-Q, Cp-Rp, Cs-Rs, Cs-D, Cs-Q, Lp-G, Lp-D, Lp-Q, Lp-Rp, Ls-Rs, Ls-D, Ls-Q, R-X, G-B, Z-θ, Y-θ
  - Ranging: Auto or fixed
  - Measurement terminal: Four-terminal pair configuration, four BNC (female) connectors
  - Cable length: 1.5 m or 3 m, automatic identification of accessories
- Test signal
  - Frequency

    Range: 1 kHz to 5 MHz

    Resolution: 1 mHz (minimum)

    Accuracy: ± 0.008 %
  - Output signal level

    Range: 10 mVrms to 250 mVrms

    Resolution: 1 mVrms

    Accuracy:

    ± (10.0 % + 1 mVrms) at the measurement port of the MFCMU

    ± (15.0 % + 1 mVrms) at the measurement port of the MFCMU cable (1.5 m or 3.0 m)
  - Output impedance: 50 Ω, typical
  - Signal level monitor

    Range: 10 mVrms to 250 mVrms

    Accuracy (open load):

    ± (10.0 % of reading + 1 mVrms) at the measurement port of the MFCMU

    ± (15.0 % of reading + 1 mVrms) at the measurement port of the MFCMU cable (1.5 m or 3.0 m)

- DC bias function
  - DC bias

    Range: 0 to ± 25 V

    Resolution: 1 mV

    Accuracy: ± (0.5 % + 5.0 mV) at the measurement port of the MFCMU or the MFCMU cable (1.5 m or 3.0 m)
  - Maximum DC bias current, supplemental characteristics:

Impedance range (Ω)	Maximum DC bias current (A)
50	10×10^{-3}
100	10×10^{-3}
300	10×10^{-3}
1×10^{3}	1×10^{-3}
3×10^{3}	1×10^{-3}
10×10^{3}	100×10^{-6}
30×10^{3}	100×10^{-6}
100×10^{3}	10×10^{-6}
300×10^{3}	10×10^{-6}

  - Output impedance: 50 Ω, typical
  - DC bias monitor

    Range: 0 to ± 25 V

    Accuracy (open load): ± (0.2 % of reading + 10 mV) at the measurement port of the MFCMU or the MFCMU cable (1.5 m or 3.0 m)
- Sweep characteristics
  - Available sweep parameters: DC bias voltage, oscillator level, frequency
  - Sweep type: linear, log
  - Sweep mode: single, double
  - Sweep direction: up, down
  - Number of measurement points: maximum 1001

- Measurement accuracy

  Measurement accuracy at the measurement port of the MFCMU or the MFCMU cable (1.5 m or 3.0 m)

  - |Z| accuracy: ± E (%)
  - θ accuracy: ± E/100 (radian)
  - C accuracy:

    ± E (%) at Dx ≤ 0.1

    ± E×$(1+Dx^2)^{1/2}$ (%) at Dx > 0.1
  - D accuracy:

    ± E/100 at Dx ≤ 0.1

    ± E×(1+Dx)/100 at Dx > 0.1
  - G accuracy:

    ± E/Dx (%) at Dx ≤ 0.1

    ± E×$(1+Dx^2)^{1/2}$/Dx (%) at Dx > 0.1

  where,

  Zx: Impedance measurement value (Ω)

  Dx: Measurement value of D

  $E = E_P' + (Z_S' / |Zx| + Y_O' \times |Zx|) \times 100$ (%)

  $E_P' = E_{PL} + E_{POSC} + E_P$ (%)

  $Y_O' = Y_{OL} + Y_{OSC} + Y_O$ (S)

  $Z_S' = Z_{SL} + Z_{OSC} + Z_S$ (Ω)

  For the parameter value, see Table 4-11 to Table 4-13. Calculation example of the measurement accuracy is also shown in Table 4-14.

  Specification conditions:

  - Temperature: 23 °C ± 5 °C
  - Integration time: 1 PLC or 16 PLC

Table 4-11 **Parameters E_{POSC}, Z_{OSC}**

Oscillator level Vosc mV	E_{POSC} %	Z_{OSC} mΩ
125 < Vosc ≤ 250	0.03×(250/Vosc - 1)	5×(250/Vosc - 1)
64 < Vosc ≤ 125	0.03×(125/Vosc - 1)	5×(125/Vosc - 1)
32 < Vosc ≤ 64	0.03×(64/Vosc - 1)	5×(64/Vosc - 1)
Vosc ≤ 32	0.03×(32/Vosc - 1)	5×(64/Vosc - 1)

Vosc is oscillator level in mV.

Table 4-12 **Parameters E_{PL}, Y_{OL}, Z_{SL}**

Cable length	E_{PL} %	Y_{OL} nS	Z_{SL} mΩ
1.5 m	0.02+3×f/100	750×f/100	5.0
3 m	0.02+5×f/100	1500×f/100	5.0

f is frequency in MHz. If measurement cable is extended, open compensation, short compensation, and load compensation must be performed.

Table 4-13 **Parameters Y_{OSC}, Y_O, E_P, Z_S**

Frequency f Hz	Y_{OSC} nS	Y_O nS	E_P %	Z_S mΩ
1k ≤ f ≤ 200k	1×(125/Vosc - 0.5)	1.5	0.095	5.0
200k < f ≤ 1M	2×(125/Vosc - 0.5)	3.0	0.095	5.0
1M < f ≤ 2M	2×(125/Vosc - 0.5)	3.0	0.28	5.0
2M < f	20×(125/Vosc - 0.5)	30.0	0.28	5.0

Vosc is oscillator level in mV.

Table 4-14 Example of calculated C/G measurement accuracy

Frequency	Measured Capacitance	C Accuracy [a]	Measured Conductance	G Accuracy [a]
5 MHz	1 pF	± 0.61 %	≤ 3 μS	± 192 nS
	10 pF	± 0.32 %	≤ 31 μS	± 990 nS
	100 pF	± 0.29 %	≤ 314 μS	± 9 μS
	1 nF	± 0.32 %	≤ 3 mS	± 99 μS
1 MHz	1 pF	± 0.26 %	≤ 628 nS	± 16 nS
	10 pF	± 0.11 %	≤ 6 μS	± 71 nS
	100 pF	± 0.10 %	≤ 63 μS	± 624 nS
	1 nF	± 0.10 %	≤ 628 μS	± 7 μS
100 kHz	10 pF	± 0.18 %	≤ 628 nS	± 11 nS
	100 pF	± 0.11 %	≤ 6 μS	± 66 nS
	1 nF	± 0.10 %	≤ 63 μS	± 619 nS
	10 nF	± 0.10 %	≤ 628 μS	± 7 μS
10 kHz	100 pF	± 0.18 %	≤ 628 nS	± 11 nS
	1 nF	± 0.11 %	≤ 6 μS	± 66 nS
	10 nF	± 0.10 %	≤ 63 μS	± 619 nS
	100 nF	± 0.10 %	≤ 628 μS	± 7 μS
1 kHz	100 pF	± 0.92 %	≤ 63 nS	± 6 nS
	1 nF	± 0.18 %	≤ 628 nS	± 11 nS
	10 nF	± 0.11 %	≤ 6 μS	± 66 nS
	100 nF	± 0.10 %	≤ 63 μS	± 619 nS

a. The calculation examples are specified under the conditions Dx = 0.1, 1 PLC integration time, 30 mVrms test signal level, and at four-terminal pair port of MFCMU.

SCUU/GSWU

SCUU: SMU CMU Unify Unit

GSWU: Guard Switch Unit

The SCUU multiplexes the outputs from two SMUs (MPSMUs and/or HRSMUs) and the CMU. The SCUU outputs are two sets of Kelvin triaxial ports (Force and Sense). The SCUU also allows the SMUs to act as DC bias sources in conjunction with the CMU. Special cables are available to connect the SMUs and CMU with the SCUU, and an auto-detect feature automatically compensates for the cable length going to the SCUU.

The GSWU contains a relay that automatically opens for IV measurements and closes for CV measurements, forming a guard return path to improve CV measurement accuracy.

- Supported SMU: MPSMU and HRSMU
- SCUU
  - Inputs

    Triaxial port: Force1, Sense1, Force2, and Sense2

    BNC port: for MFCMU

    Control port: for MFCMU
  - Outputs

    Triaxial port: Force1/CMUH, Sense1, Force2/CMUL, and Sense2

    Control port: for GSWU

    LED: SMU/CMU output status indicator
  - Docking mode

    Direct and indirect mode
- GSWU
  - Input

    Control port: for SCUU

    Mini pin plug port: Guard1 and Guard2
  - Output

    LED: Connection status indicator

- SCUU supplemental characteristics
  - SMU path

    Offset current: < 20 fA

    Offset voltage: < 100 μV at 300 sec

    Closed channel residual resistance: < 200 mΩ

    Channel isolation resistance: > 10^{15} Ω
  - CMU path
    - Test signal
      - Signal output level additional errors (CMU bias, open load):

        ± 2 % (direct docking)

        ± 7 % (indirect docking)
      - Signal output level additional errors (SMU bias, open load):

        ± 5 % (direct docking, ≥ 10 kHz)

        ± 10 % (indirect docking, ≥ 10 kHz)
      - Output impedance: 50 Ω, typical
      - Signal level monitor additional errors (open load):

        ± 2 % (CMU bias), direct docking

        ± 5 % (SMU bias), direct docking

        ± 7 % (CMU bias), indirect docking

        ± 10 % (SMU bias), indirect docking
    - DC bias function
      - DC voltage bias (CMU bias)

        Range: 0 to ± 25 V

        Resolution: 1 mV

        Additional errors (for CMU bias): ± 100 μV (open load)
      - DC voltage bias (SMU bias)

        Range: 0 to ± 100 V

        Resolution: 5 mV

Additional errors (for SMU voltage output accuracy): ± 100 μV (open load)

- DC bias monitor additional errors (open load):

  ± 20 mV, direct docking

  ± 30 mV, indirect docking

- Output impedance: 50 Ω, typical
- DC output resistance: 50 Ω (CMU bias), 130 Ω (SMU bias)

- Measurement accuracy

  Impedance measurement error is given by adding the following additional error Ee to the MFCMU measurement error.

  Ee = ± (A + Zs / |Zx| + Yo× |Zx|) × 100 (%)

  Zx: Impedance measurement value (Ω)

  A: 0.05 % (direct docking) or 0.1 % (indirect docking)

  Zs: 500 × (1 + f) mΩ (f: frequency in MHz)

  Yo: 1 + f × 10 nS (direct docking, × 2 for indirect docking)

  When the measurement terminals are extended by using the measurement cable, the measurement accuracy is applied to the data measured after performing the open/short/load correction at the DUT side cable end.

  Specification conditions:

  - Temperature: 23 °C ± 5 °C
  - Integration time: 1 PLC or 16 PLC

HV-SPGU

HV-SPGU: High Voltage Semiconductor Pulse Generator Unit

- Number of output channels: 2 channels per module
- Modes: pulse, constant, and free run
- Standard pulse mode
  - Two level pulse
  - Three level pulse per one channel
  - Pulse period: 30 ns to 10 s
- Delay range: 0 s to 9.99 s
- Delay resolution: minimum 2.5 ns
- Output count: 1 to 1,000,000
- Voltage monitor minimum sampling period: 5 µs
- Trigger output

  Level: TTL

  Timing: Synchronized with pulse period

  Trigger width: Pulse period × 1/2 (pulse period ≤ 10 µs), maximum 5 µs (pulse period > 10 µs)
- Pulse range and pulse parameter: See Table 4-15.
- Pulse/DC output voltage and accuracy: See Table 4-16.

Figure 4-1 SPGU pulse setup parameters

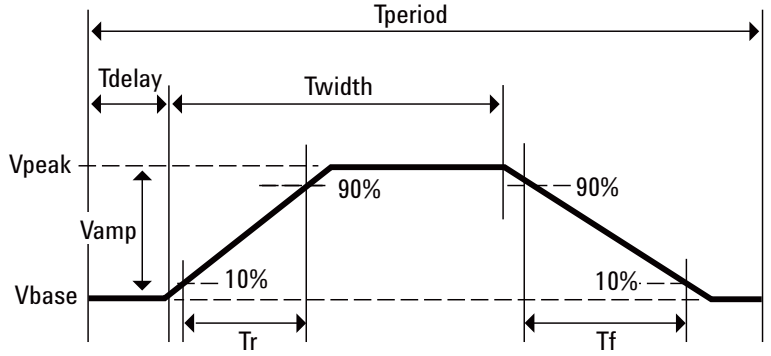


Table 4-15 Pulse range and pulse parameter

Item		Value [a]
Frequency range		0.1 Hz to 33 MHz
Pulse period	Programmable range	30 ns to 10 s
	Resolution	10 ns
	Minimum	100 ns (Vamp ≤ 10 V)
	Accuracy	± 1 % (± 0.01 % [b])
Pulse width	Programmable range	10 ns to (period - 10 ns)
	Resolution	2.5 ns (Tr and Tf ≤ 8 μs)
		10 ns (Tr or Tf > 8 μs)
	Minimum	50 ns (25 ns, typical) at Vamp ≤ 10 V
	Accuracy	± (3 % + 2 ns)
Transition time (leading time Tr and trailing time Tf) [c]	Programmable range	8 ns to 400 ms (see below for the minimum transition time)
	Resolution	2 ns (Tr and Tf ≤ 8 μs)
		8 ns (Tr or Tf > 8 μs)
	Minimum (typical)	< 15 ns (Vamp ≤ 10 V)
	Minimum	20 ns (Vamp ≤ 10 V)
		30 ns (Vamp ≤ 20 V)
		60 ns (Vamp > 20 V)
	Accuracy	-5 % to 5 % + 10 ns (Vamp ≤ 10 V)
		-5 % to 5 % + 20 ns (Vamp ≤ 20 V)
Output relay switching time [d]	Open/close	< 100 μs

a. Unless otherwise stated, all specifications assume a 50 Ω termination.
b. Typical minimum. This is the supplemental characteristics.
c. The time from 10 % to 90 % of Vamp which is the amplitude of output pulse.
d. The time it takes the open state relay to open or close.

Table 4-16 **Pulse/DC output voltage and accuracy**

Item	Value	Condition
Output voltage (Vout)	-20 V to +20 V	50 Ω load
	-40 V to +40 V	open load
Accuracy [a]	± (0.5 % + 50 mV)	open load
Amplitude resolution	0.2 mV (± 10 V range)	50 Ω load
	0.8 mV (± 40 V range)	
	0.4 mV (± 10 V range)	open load
	1.6 mV (± 40 V range)	
Output connectors	SMA	
Source impedance	50 Ω [b]	
Short circuit current	800 mA peak (400 mA average [c])	
Overshoot/pre-shoot/ringing [d]	± (5 % + 20 mV)	50 Ω load
Output limit	Monitoring over current limit	

a. At 1 μs after completing transition.
b. Typical (± 1 %)
c. Specification condition: $N \times 0.2 + Itotal < 3.0$ A where, N is the number of installed HV-SPGUs, and *Itotal* is DC current output by all modules (including HV-SPGUs)
d. Following the specified condition with transition time.

- ALWG (arbitrary linear waveform generator) function

  Arbitrary linear waveform generator (ALWG) mode

  - Output complex waveform per one channel of HV-SPGU
  - Define multi-level pulse and multi-pulse waveform including open state pulse with ALWG GUI editor
  - Sequential pulse waveform from user-defined pulse waveform
  - 1024 points per one channel

  - Programmable timing range: 10 ns to 671.088630 ms, 10 ns resolution
- SPGU supplemental characteristics
  - Pulse width jitter: 0.001 % + 150 ps
  - Pulse period jitter: 0.001 % + 150 ps
  - Maximum slew rate: 1000 V/μs (50 Ω load)
  - Noise: 10 mVrms (at DC output)
  - Advanced feature:

    Voltage monitor: The HV-SPGU has a voltage monitor function to measure the voltage at the DUT terminal.

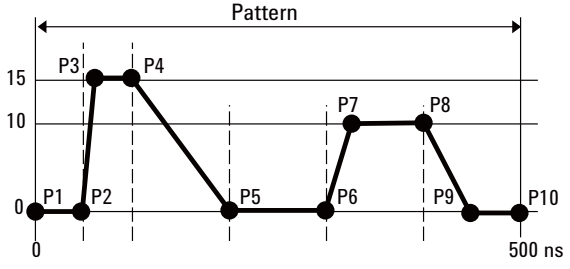
    Measurement accuracy (open load): ± (0.1 % of reading + 25 mV)

    Measurement resolution: 50 μV

    Note: Specified at 1 PLC (20 ms = (5 μs sample + 5 μs interval)× 2000 samples)

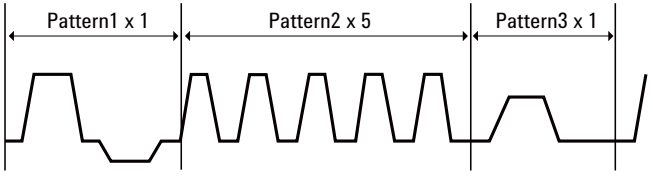
    Voltage compensation: The HV-SPGU can measure the impedance of DUT and adjust the output voltage according to the DUT impedance.

Figure 4-2 **ALWG setup table and pattern example**



Point	Time	Voltage
1	0	0.0 V
2	50 ns	0.0 V
3	70 ns	15.0 V
4	100 ns	15.0 V
5	200 ns	0.0 V
6	300 ns	0.0 V
7	320 ns	10.0 V
8	400 ns	10.0 V
9	450 ns	0.0 V
10	500 ns	0.0 V

Figure 4-3 **ALWG complex waveform example**



Selector

Keysight 16440A (B1500A-A04) SMU/pulse generator selector switches either a SMU or PGU to the associated output port. You can expand to four channels by adding an additional selector. The PGU port on channel 1 provides a "PGU OPEN" function, which can disconnect the PGU by opening a semiconductor relay. Keysight B1500A and 16445A are required to use the selector.

The following specifications data is specified at 23 °C ± 5 °C (73 °F ± 9 °F) and 50 % relative humidity.

- Channel configuration: 2 channels (CH 1 and CH 2). Can add the additional 2 channels (CH 3 and CH 4) by adding another selector (selector expander).

	Input	Output
Channel 1 (CH 1)	2 (SMU and PGU [a])	1
Channel 2 (CH 2)	2 (SMU and PGU)	1
Channel 3 (CH 3) [b]	2 (SMU and PGU [a])	1
Channel 4 (CH 4) [b]	2 (SMU and PGU)	1

a. PGU channels 1 and 3 have a built-in series semiconductor relay.
b. Available when a selector expander is installed.

- Voltage and current range

Input port	Maximum voltage (V)	Maximum current (A)
SMU	200	1.0
PGU	40	0.4 [a]

a. This is peak-to-peak ac current. For 50 Ω load. If DUT impedance is lower than 50 Ω, SPGU output voltage should be decreased for preventing the selector from over current.

Selector Adapter

Keysight 16445A selector adapter is required to control and to supply DC power to the selector.

- Power requirement: 100 to 240 V, 50/60 Hz
- Maximum volt-amps (VA): 20 VA

WGFMU/RSU

WGFMU: Waveform Generator/Fast Measurement Unit

RSU: Remote-sense and Switch Unit

The WGFMU is a self-contained module offering the combination of arbitrary linear waveform generation (ALWG) with synchronized fast current or voltage (IV) measurement. The ALWG function allows you to generate not only DC, but also various types of AC waveforms. In addition to this versatile sourcing capability, the WGFMU can also perform measurement in synchronization with the applied waveform, which enables accurate high-speed IV characterization.

- Number of output channels: 2 channels per module
- Modes: Fast IV, PG (pulse generator), DC, and SMU pass-through
- Measurement functions: See Table 4-17.
- Voltage force accuracy, resolution, and timing: See Table 4-18.
- Voltage measurement accuracy, resolution and noise: See Table 4-19.
- Current measurement accuracy and resolution: See Table 4-20.
- RF electromagnetic field and WGFMU measurement accuracy

  The voltage and current measurement accuracy and the timing accuracy between modules may be affected by RF electromagnetic field of strength over 3 V/m at frequencies 80 MHz to 1 GHz and 1.4 GHz to 2.0 GHz, and 1 V/m at frequencies 2.0 GHz to 2.7 GHz. The extent of this effect depends upon the installation condition how the instrument is positioned and shielded.
- RSU
  - Output terminal
    - Connector: SMA
    - Source impedance: 50 Ω (nominal), at DC output in PG mode
  - SMU path
    - Maximum voltage: ± 25 V
    - Maximum current: ± 100 mA
  - V Monitor terminal
    - Connector: BNC
    - Source impedance: 50 Ω (nominal), at DC output

The V Monitor terminal outputs a buffered signal equal to 1/10 of the Output terminal voltage (into a 50 Ω load).

- WGFMU to RSU cable length

  The WGFMU and RSU are connected by a special composite cable. The following configurations are available.

  - 3 m
  - 5 m
  - 1.5 m
  - 2.4 m + connector adapter + 0.6 m
  - 4.4 m + connector adapter + 0.6 m

  Note: The connector adapter is used when routing the cable through the prober's connector panel.

- ALWG function: See Table 4-21.
- Trigger output

  Level: TTL

  Trigger width: 10 ns

  Generated synchronously with ALWG waveform.

- Software

  - Instrument library for WGFMU control
  - NBTI and general-purpose EasyEXPERT Application Tests
  - Sample programs (NBTI and general-purpose measurement using WGFMU and RTS data analysis)

- WGFMU supported prober vendors

  Cascade Microtech

  Suss MicroTec

  Vector Semicon

  Note: The maximum number of installable RSUs for a given prober depends upon the available space. Please contact your local sales representative for details on connecting and mounting the WGFMU and RSU.

- WGFMU supplemental data
  - RSU SMU path

    Leakage current: < 100 pA

    Residual resistance: < 300 mΩ
  - Jitter: < 1 ns
  - Skew between channels: < 3 ns, under no electrostatic discharge condition
  - Trigger output skew: < 3 ns
  - Current range change time: < 150 µs

    This is the time until the measured current settles within ± 0.3 % of the final result value after the range change.
  - Minimum timing parameters for current measurement: See Table 4-22.
  - Minimum timing parameters for voltage measurement: See Table 4-23.

Table 4-17 Measurement functions, voltage forcing, voltage measurement, and current measurement

Mode	Function	V force ranges	V measure ranges	I measure ranges
Fast IV	V force/ I measure, V force/ V measure	-3 V to +3 V, -5 V to +5 V, -10 V to 0 V, 0 V to +10 V	-5 V to +5 V, -10 V to +10 V	1 µA, 10 µA, 100 µA, 1 mA, 10 mA
PG	V force/ V measure	-3 V to +3 V, -5 V to +5 V	-5 V to +5 V	-
DC	V force/ I measure, V force/ V measure	-3 V to +3 V, -5 V to +5 V, -10 V to 0 V, 0 V to +10 V	-5 V to +5 V, -10 V to +10 V	1 µA, 10 µA, 100 µA, 1 mA, 10 mA
SMU pass through	Measurement using SMU	Maximum ± 25 V	-	Maximum ± 100 mA

Table 4-18 Voltage force accuracy, resolution, and timing

V force (Fast IV mode)	-5 V to +5 V, -10 V to 0 V, 0 V to +10 V
V force (PG mode)	-5 V to +5 V, open load -2.5 V to +2.5 V, 50 Ω load
Accuracy	± 0.1 % of setting ± 0.1 % of range [a]
Resolution [b]	96 μV (-3 V to +3 V) 160 μV (all ranges except for -3 V to +3 V)
Overshoot/undershoot	± (5 % + 20 mV) [c]
Noise	Maximum 0.1 mV_{rms} [d]
Rise time T_{rise} (10 to 90 %)/ Fall time T_{fall} (90 to 10 %)	Accuracy: -5 % to +(5 % + 10 ns) of setting [e]
	Minimum: 24 ns, PG mode and 50 Ω load
Pulse period	Timing accuracy: ± 1 % of setting [f]
	Minimum: 100 ns, PG mode and 50 Ω load
Pulse width	Accuracy: ± (3 % + 2 ns) [g]
	Minimum: 50 ns, PG mode and 50 Ω load

a. Independent of the range or the mode. DC constant voltage output. Load impedance must be ≥ 1 MΩ (1 μA range) or ≥ 200 kΩ (all other current ranges) for Fast IV mode, or ≥ 1 MΩ for PG mode.
b. Can vary at most 5 % based on the result of calibration
c. PG mode, 50 Ω load, T_{rise} and T_{fall} >16 ns with the 1.5 m cable, >32 ns with 3 m cable, or >56 ns with 5 m cable
d. Theoretical value for the observed time 100 ns to 1 ms, supplemental characteristics
e. PG mode, 50 Ω load, T_{rise} and T_{fall} ≥ 24 ns
f. PG mode, 50 Ω load, pulse period ≥ 100 ns
g. PG mode, 50 Ω load, pulse width ≥ 50 ns

Table 4-19 Voltage measurement accuracy, resolution, and noise

Accuracy	± (0.1 % of reading + 0.1 % of range) [a]
Resolution [b]	680 μV, -5 V to +5 V range 1.4 mV, -10 V to +10 V range
Noise [c]	Maximum 4 mV_{rms} (-5 V to +5 V range)

a. Independent of the range or the mode. DC constant voltage output. Applicable condition: 10,000 averaging samples for 10 μA range and above; 100,000 averaging samples for the 1 μA range
b. Display resolution. Can vary at most 5 % based on the result of calibration
c. 0 V output, open load, no averaging. Maximum 1.5 mV_{rms} as supplemental characteristics

Table 4-20 Current measurement accuracy, resolution, and noise

Accuracy	± (0.1 % of reading + 0.2 % of range) [a]
Resolution [b]	0.014 % of range
Noise (Effective resolution)	Maximum 0.2 % of range [c]

a. Independent of the range or the mode. DC constant voltage output. Applicable condition: 10,000 averaging samples for 10 μA range and above; 100,000 averaging samples for the 1 μA range
b. Display resolution. Can vary at most 5 % based on the result of calibration
c. Effective value at 0 V output, open load, and no averaging. Supplemental characteristics

Table 4-21 ALWG and sampling measurement capability

Maximum number of vectors	2048
Maximum number of sequences	512
Maximum number of loop counts	1 to 10^{12}
Length of a vector	10 ns to 10,000 s with 10 ns resolution
Sampling rate	5 ns, or 10 ns to 1 s with 10 ns resolution
Averaging time	10 ns to 20 ms with 10 ns resolution
Hardware memory	About 4 M data points/channel (typical)

Table 4-22 Minimum timing parameters for current measurement[1]

Voltage applied to DUT		10 V					
Current applied to DUT		100 nA	1 μA	10 μA	100 μA	1 mA	10 mA
Applied voltage condition	Recommended minimum pulse width[a]	47 μs	38.7 μs	6.8 μs	950 ns	240 ns	145 ns
Current measurement condition	Measurement Range	1 μA	1 μA	10 μA	100 μA	1 mA	10 mA
	Recommended minimum measurement window	10 μs	1.64 μs	1 μs	130 ns	40 ns	20 ns
	Settling time[b]	37 μs	37 μs	5.8 μs	820 ns	200 ns	125 ns
	Noise (rms)[c]	160 pA	425 pA	2.5 nA	47 nA	280 nA	1.9 μA

a. Recommended minimum pulse width = settling time + recommended minimum measurement window.
b. The time until the measured value settles to within ± 0.6 % of the final result value after the output voltage is changed from the initial value (0 V). Minimum rise/fall time of 70 ns is recommended for minimizing overshoot.
c. RMS noise measured over the recommended minimum measurement window.

1. Measurement conditions: The DUT is a resistive load chosen to adjust the flowing current to the specified current in the table above. The capacitance of the cable between the RSU and the DUT is 20 pF. Voltage is applied to the DUT by a channel of WGFMU/RSU in Fast IV mode and in the 10 mA range, and current measurement is performed by another channel at 0 V in Fast IV mode.

Table 4-23 Minimum timing parameters for voltage measurement[1]

Voltage applied to DUT		5 V	10 V
Applied voltage condition	Recommended minimum pulse width[a]	105 ns	130 ns
Voltage measurement condition	Measurement Range	5 V	10 V
	Recommended minimum measurement window	20 ns	20 ns
	Settling time[b]	85 ns	110 ns
	Noise (rms)[c]	1.4 mV	1.4 mV

a. Recommended minimum pulse width = settling time + recommended minimum measurement window.
b. The time until the measured value settles to within ± 0.6 % of the final result value after the output voltage is changed from the initial value (0 V). Minimum rise/fall time of 70 ns for 10 V, or 30 ns for 5 V is recommended for minimizing overshoot.
c. RMS noise measured over the recommended minimum measurement window.

1. Measurement conditions: The DUT is a resistive load between 1 kΩ and 10 MΩ. The capacitance of the cable between the RSU and the DUT is 20 pF. Voltage is applied to the DUT by a channel of WGFMU/RSU, and voltage measurement is performed by the same channel. (PG mode for 5 V, Fast IV mode for 10 V)

EasyEXPERT Software

Operation mode

- Application test mode

  Realizes application oriented point-and-click test setup and execution. You can select a test definition from library by device type and measurement item, and execute the test after changing setup parameter values as needed. Also see "Application library".

- Classic test mode

  Realizes function oriented test setup and execution with the same look, feel, and terminology of Keysight 4155/4156 user interface. In addition, it improves the user interface by taking full advantage of EasyEXPERT's GUI features.

- Tracer test mode (Curve tracer mode)

  Realizes intuitive and interactive sweep control by using a rotary knob, similar to a curve tracer. Just like an analog curve tracer, you can sweep in only one direction (useful for R&D device analysis) or in both positive and negative directions (useful in failure analysis applications). Test setups can be saved, and used in the classic test mode for further detailed measurement and analysis. Also see "Oscilloscope view".

- Quick test mode

  A GUI-based quick test mode enables you to perform test sequencing without programming. You can select, copy, rearrange, and cut-and-paste any test setups with a few simple mouse clicks. Once you have selected and arranged your tests, simply click on the measurement button to begin running an automated test sequence.

Application library

Contains over 300 application test definitions conveniently organized by device type, application, and technology. You can easily edit and customize the furnished application tests to fit your specific needs.

The following table shows a part of tests included in the library. They are subject to change without notice.

Category	Test items
CMOS	Id-Vg, Id-Vd, Vth, breakdown, capacitance, QSCV, etc.
BJT	Ic-Vc, diode, Gummel plot, breakdown, hfe, capacitance, etc.
Discrete	Id-Vg, Id-Vd, Ic-Vc, diode, etc.
Memory	Vth, capacitance, endurance test, etc.
PwrDevice	Pulsed Id-Vg, pulsed Id-Vd, breakdown, etc.
NanoTech	Resistance, Id-Vg, Id-Vd, Ic-Vc, etc.
Reliability	NBTI/PBTI, charge pumping, electromigration, hot carrier injection, J-Ramp, TDDB, etc.

Oscilloscope view

Available for the tracer test using MCSMU modules. The oscilloscope view displays MCSMU current or voltage measurement data versus time. The pulsed measurement waveforms appear in a separate window for easy verification of the measurement timings. This function is useful for verifying waveform timings and debugging pulsed measurements. It is available when a tracer test has one or more MCSMU channels being used in pulsed mode. The oscilloscope view can display the pulse waveform at any (user specified) sweep step of the sweep output.

- Sampling interval: 2 μs
- Sampling points: 2000 Sa
- Sampling duration: 22 μs to 24 ms
- Marker function

  Data read-out for each channel

  Resolution: 2 μs
- Data saving

  Numeric: TXT/CSV/XMLSS

  Image: EMF/BMP/JPG/PNG

Measurement modes

Supports the following measurement modes.

- IV measurement
  - Spot
  - Staircase sweep
  - Pulsed spot
  - Pulsed sweep
  - Staircase sweep with pulsed bias
  - Sampling
  - Multi-channel sweep
  - Multi-channel pulsed sweep
  - List sweep
  - Linear search (*1)
  - Binary search (*1)
- C measurement
  - Spot C
  - CV (DC bias) sweep
  - Pulsed spot C (*1)
  - Pulsed sweep CV (*1)
  - C-t sampling (*1)
  - C-f sweep (*1)
  - CV (AC level) sweep (*1)
  - Quasi-static CV (QSCV) (*1)

(*1) Direct Control classic test is used.

Sweep measurement

Number of steps: 1 to 10001 (SMU), 1 to 1001 (CMU)

Sweep mode: linear or logarithmic (log)

Sweep direction: single or double

Hold time: 0 to 655.35 s, 10 ms resolution

Delay time: 0 to 65.535 s or 655.35 s for CV (AC level) sweep and C-f sweep, 100 μs resolution

Step delay time: 0 to 1 s, 100 μs resolution

Step output trigger delay time: 0 to (delay time) s, 100 μs resolution

Step measurement trigger delay time: 0 to 65.535 s, 100 μs resolution

Sampling (time domain) measurement

Performs the voltage/current measurement in the specified time interval and plots the measured data versus time.

Sampling channels: up to 10

Sampling mode: linear or logarithmic (log)

Sampling points: 1 to 100001/(number of channels) for linear sampling, 1 to 1 + (number of data for 11 decades) for log sampling

Sampling interval range: 100 μs + 20 μs × (number of channels - 1) to 2 ms in 10 μs resolution for linear sampling, or 2 ms to 65.535 s in 1 ms resolution for both linear and log sampling

Hold time, bias hold time: -90 ms to -100 μs in 100 μs resolution, 0 to 655.35 s in 10 ms resolution

Measurement time resolution: 100 μs

Other measurement characteristics

- Measurement control:

  Single, repeat, append, and stop

- SMU setting capabilities:

  Limited auto ranging, voltage/current compliance, power compliance, automatic sweep abort functions, self-test, and self-calibration

- Standby mode

  If the standby mode is ON, only the standby channels remain programmed to their specified output value in the non-measurement status.

- Bias hold function

  This function allows you to keep a source active between measurements. The source module will apply the specified bias between measurements when running classic tests inside an application test, in quick test mode, or during a repeated measurement. The function ceases as soon as these conditions end or when a measurement that does not use this function is started.

- Current offset cancel

  This function subtracts the offset current from the current measurement raw data, and returns the result as the measurement data. This function is used to compensate the error factor (offset current) caused by the measurement path such as the measurement cables, manipulators, or probe card.

- Time stamp

  Time stamp function utilizing an internal quartz clock. Resolution: 100 μs

Data display

- X-Y graph plot

  X-axis and up to eight Y-axes. Linear and log scale. Real time graph plotting.

  X-Y graph plot can be printed or stored as image data to clip board or mass storage device. The formats BMP, GIF, PNG, and EMF are supported.

  - Scale

    Auto scale and zoom

  - Marker

    Marker to min/max, interpolation, direct marker, and marker skip

  - Cursor

    Direct cursor

  - Line

    Two lines, normal mode, grad mode, tangent mode, and regression mode

  - Overlay graph comparison

    Graphical plots can be overlaid for comparison.

- List display

  Measurement data and calculated user function data are listed in conjunction with sweep step number or time domain sampling step number. Up to 20 data sets can be displayed.

- Data variable display

  Up to 20 user-defined parameters can be displayed.

Automatic analysis function

On a graphics plot, the markers and lines can be automatically located using the auto analysis setup. Parameters can be automatically determined using automatic analysis, user function, and read out functions.

- Analysis functions

  Up to 20 user-defined analysis functions can be defined using arithmetic expressions.

  Measured data, pre-defined variables, and read out functions can be used in the computation. The results can be displayed on the LCD.

- Read out functions

  Built-in functions for reading various values related to the marker, cursor, or line

Arithmetic functions

- User functions

  Up to 20 user-defined functions can be defined using arithmetic expressions.

  Measured data and pre-defined variables can be used in the computation. The results can be displayed on the LCD.

- Arithmetic operators

  +, -, *, /, ^, abs (absolute value), at (arc tangent), avg (averaging), cond (conditional evaluation), delta, diff (differential), exp (exponent), integ (integration), lgt (logarithm, base 10), log (logarithm, base e), mavg (moving average), max, min, sqrt, trigonometric function, inverse trigonometric function, and so on

- Physical constants assigned to the keys

  - q: Electron charge, 1.602177E-19 C
  - k: Boltzmann constant, 1.380658E-23 J/K
  - ε (e): Dielectric constant of vacuum, 8.854188E-12 F/m

- Numeric constants assigned to the keys

  a (10^{-18}), f (10^{-15}), p (10^{-12}), n (10^{-9}), u or μ (10^{-6}), m (10^{-3}), k (10^{3}), M (10^{6}), G (10^{9}), T (10^{12}), P (10^{15})

Workspace and data management

- Workspace

  Separate work environment for EasyEXPERT. Every workspace supports the following features.

  - Measurement setup and execution
  - Save/Recall My Favorite (preset group) setup
  - Save/Recall measurement data and settings
  - Import/Export device definition, measurement settings, My Favorite setup, measurement data, and application library
  - Test result data management
  - Access authority (private/public) setting

- Data auto record / auto export

  EasyEXPERT has the ability to automatically store the measurement setup and data within a workspace. It can also export measurement data in real time. You can save data to any storage device connected to the PC.

- Import/export files

  File type: EasyEXPERT format, XML-SS format, CSV format

- Workspace management

  EasyEXPERT has the ability to import/export a workspace for back-up and portability.

External instrument control

- Switching matrix operation panel (GUI)

  Keysight B2200A, B2201A, and E5250A with E5252A cards

- External instruments supported by application tests

  Keysight 4284A/E4980A, 81110A, and 3458A

- Wafer prober control

  Scripts to perform chuck move/up/down and subsite move for major semi-automatic probers are furnished. The wafer prober control can be performed in the repeat measurement process.

Program and interface capabilities

- Data storage

  Hard disk drive, DVD-R drive

- Interfaces

  GPIB, interlock, USB (USB 2.0, 2 ea. on front, 2 ea. on rear), LAN (1000BASE-T/100BASE-TX/10BASE-T), trigger in/out, digital I/O, VGA video output

- Remote control capabilities

  FLEX commands (GPIB)

  EasyEXPERT remote control function (LAN)

- Trigger I/O

  Only available using GPIB FLEX commands.

  Trigger in/out synchronization pulses before and after setting and measuring DC voltage and current. Arbitrary trigger events can be masked or activated independently.

Furnished Software

- Prober control scripts
- Desktop EasyEXPERT software
- VXI*plug*&*play* driver for Keysight B1500A
- 4155/56 setup file converter

  Converts the measurement setup file (extension MES or DAT) for Keysight 4155 and 4156 into the equivalent setup file for EasyEXPERT classic test mode.

- MDM file converter

  Converts the EasyEXPERT test result data file (extension XTR or ZTR) to Keysight IC-CAP MDM file. Supports the data of the following classic tests.

  - I/V Sweep
  - Multi Channel I/V Sweep
  - C-V Sweep

NOTE For the latest system requirements, go to www.keysight.com and type in B1500A in the Search field at the top of the page.

Desktop EasyEXPERT Software

Provides almost the same capability, look and feel of EasyEXPERT on a PC.

- Execution mode

  Online and offline

- Supported instruments
  - B1500A
  - B1505A
  - 4155B, 4156B, 4155C, and 4156C

    Firmware:
    - HOSTC: 03.08 or later
    - SMUC: 04.08 or later
- Supported 4155/4156 functionality
  - I/V sweep
  - I/V-t sampling (except thinned out mode)
  - VSU/VMU (except differential voltage measurement using VMU)
  - PGU (41501B)
  - Switching matrix control

General Specifications

- Temperature range

  Operating: +5 °C to +40 °C

  Storage: -20 °C to +60 °C
- Humidity

  Operating: 20 % to 70 %RH, non-condensing

  Storage: 10 % to 90 %RH, non-condensing
- Altitude

  Operating: 0 to 2,000 m (6,561 ft.)

  Storage: 0 to 4,600 m (15,092 ft.)
- Power requirement: 100-240 V (±10 %), 50/60 Hz
- Maximum volt-amps (VA): 900 VA
- Regulatory compliance
  - EMC

    IEC 61326-1 / EN 61326-1

    ICES/NMB-001

    AS/NZS CISPR 11

    KC: RRA Notification amending Radio Waves Act Article 58-2
  - Safety

    IEC 61010-1 / EN 61010-1

    CAN/CSA-C22.2 No. 61010-1
- Dimensions

  B1500A: 420 mm (W) × 330 mm (H) × 575 mm (D)

  B1531A RSU: 45.2 mm (W) × 70 mm (H) × 82 mm (D)

  E5288A ASU: 132 mm (W) × 88.5 mm (H) × 50 mm (D)

  N1255A Connection box: 184.4 mm (W) × 61.6 mm (H) × 169.6 mm (D)

  N1301A-100 SCUU: 148 mm (W) × 75 mm (H) × 70 mm (D)

  N1301A-200 GSWU: 33.2 mm (W) × 41.5 mm (H) × 32.8 mm (D)

16440A Selector: 250 mm (W) × 50 mm (H) × 275 mm (D)

16445A Selector adapter: 250 mm (W) × 50 mm (H) × 260 mm (D)

- Weight

  B1500A (empty): 20 kg

  B1510A: 2.0 kg

  B1511B: 1.0 kg

  B1514A: 1.3 kg

  B1517A: 1.2 kg

  B1520A: 1.5 kg

  B1525A: 1.3 kg

  B1530A: 1.3 kg

  B1531A: 0.13 kg

  E5288A: 0.5 kg

  N1255A: 0.7 kg

  N1301A-100: 0.8 kg

  N1301A-200: 0.1 kg

  16440A: 1.1 kg

  16445A: 1.0 kg

5 Accessories and Options

KEYSIGHT TECHNOLOGIES

Furnished accessories, available accessories, and available options of Keysight B1500A Semiconductor Device Analyzer are described in this chapter.

Table 5-1 Furnished Accessories

Description	Quantity
USB keyboard	1
USB mouse	1
Stylus pen	1
Interlock cable, 1.5 m or 3.0 m	1
GNDU cable, 1.5 m or 3.0 m	1
GNDU Kelvin adapter[a]	1
Triaxial cable[a], 1.5 m or 3.0 m	1
SMU number label, only for the B1500A installed with SMU	1
PG number label, only for the B1500A installed with SPGU	1
Power cable	1
Disk set for Keysight 4155B/4155C/4156B/4156C firmware update	1
Software CD (including VXI*plug*&*play* driver and utility tools)	1
WGFMU instrument library and sample program CD	1
Desktop EasyEXPERT CD	1
License-to-use for EasyEXPERT and Desktop EasyEXPERT	

a. GNDU Kelvin adapter must be directly connected to the B1500A GNDU connector for taking out the GNDU Force and Sense to the individual connectors. Then the GNDU cable must be used for extending the GNDU Force. And the triaxial cable must be used for the Sense.

Cable length 1.5 m or 3.0 m is specified by the option B1500A-015 or B1500A-030.

Table 5-2 Options

Option Item	Description
B1500A-015	1.5 m length of bundled cables
B1500A-030	3.0 m length of bundled cables
B1500A-050	50 Hz power line frequency
B1500A-060	60 Hz power line frequency
B1500A-A00	Empty package for custom solution, contains no measurement module
B1500A-A01	Standard package, contains four MPSMU and eight triaxial cables
B1500A-A02	High resolution package, contains four HRSMU and eight triaxial cables
B1500A-A03	High power package, contains two HPSMU, two MPSMU, and eight triaxial cables
B1500A-A04	Flash memory cell measurement basic package, see Table 5-3
B1500A-A10	HPSMU add-on package, adds one HPSMU and two triaxial cables
B1500A-A11	MPSMU add-on package, adds one MPSMU and two triaxial cables
B1500A-A17	HRSMU add-on package, adds one HRSMU and two triaxial cables
B1500A-A1A	Add-on package, adds one MCSMU, two triaxial cables, and one N1255A
B1500A-A1B	Add-on package, adds two MCSMU, four triaxial cables, and one N1255A
B1500A-A20	Capacitance measurement add-on package, adds the MFCMU and one CMU cable
B1500A-A25	HVSPGU add-on package, adds one HVSPGU and two SPGU cables
B1500A-A28	Add-on package for HRSMU, adds one ASU, one D-sub cable, and one triaxial cable
B1500A-A29	Add-on package for MPSMU, adds one ASU, one D-sub cable, and one triaxial cable
B1500A-A30	WGFMU add-on package, adds one WGFMU, two RSU, and two RSU cables
B1500A-A31	WGFMU add-on package with connector adapters, see Table 5-4
B1500A-A3P	WGFMU probe cable kit, see Table 5-5
B1500A-A5F	Test fixture for package device measurement, adds one 16442B, see Table 5-6
B1500A-A6J	ANSI Z540 compliant calibration
B1500A-ABA	Paper manual set, English
B1500A-ABJ	Paper manual set, Japanese
B1500A-DR1	Changing DVD-R drive to DVD-ROM drive
B1500A-UK6	Commercial calibration certificate with test data

Table 5-3 **B1500A-A04 Basic Flash Memory Cell Package**

Description	Quantity
Medium power source/monitor unit (MPSMU)	2
High resolution source/monitor unit (HRSMU)	2
High voltage semiconductor pulse generator unit (HVSPGU)	1
SPGU cable, 1.5 m or 3.0 m	2
16440A SMU/PGU pulse generator selector	1
16445A selector adapter for 16440A	1
Control cable, 1.5 m, between B1500A and 16445A	1
Control cable, 40 cm, between 16445A and 16440A	1
Triaxial cable, 1.5 m, between B1500A and 16440A	2
Triaxial cable, 1.5 m or 3.0 m	8

Table 5-4 **B1500A-A31[1] WGFMU Add-on Package with Connector Adapter**

Description	Quantity
Waveform generator/fast measurement unit (WGFMU)	1
Remote-sense and switch unit (RSU)	2
RSU cable, 2.4 m, between WGFMU and connector adapter	2
RSU cable, 0.6 m, between RSU and connector adapter	2
16493R-801 connector adapter (female-female)	2

1. The option B1500A-A31 cannot be selected with the option B1500A-015.

Table 5-5 B1500A-A3P WGFMU Probe Cable Kit

Description	Quantity
16493R-101 SSMC short-open cable for current return path, 50 mm	2
16493R-102 SSMC short-open cable for current return path, 75 mm	2
16493R-202 SMA-SSMC cable between RSU and DC probe, 200 mm	2
16493R-302 SMA-SMA cable between RSU and RF probe, 200 mm	2

Table 5-6 B1500A-A5F[1] Test Fixture for Package Device Measurement

Description	Quantity
16442B test fixture	1
Accessory case	1
Blank PTFE board for DUT stage	1
28-pin DIP (dual-in-line) package socket module	1
Universal socket module, 0.075 inch pitch	1
Universal socket module, 0.05 inch pitch	1
Connection pin set for universal socket module	10
Connection wire, mini banana to pin plug	4/color
Connection wire, pin plug to pin plug	3/color
Connection wire, mini banana to mini clip	3/color
Connection wire, mini banana to mini banana	3/color

1. Contains four types of the connection wire. There is three colors for each connection wire, black, red, and blue.

Table 5-7 Available Accessories

Model Number	Option Item	Description
16440A		SMU/PGU pulse generator selector
	16440A-001	Control cable, 1.5 m
	16440A-002	Control cable, 3.0 m
	16440A-003	Control cable, 40 cm for second selector
16442B		Test fixture
	16442B-010	Add triaxial cables, 1.5 m, 4 ea.
	16442B-011	Add triaxial cables, 3 m, 4 ea.
	16442B-800	Extra blank PTFE board
	16442B-801	Universal socket module, 0.1 inch pitch, with 10 pins
	16442B-802	Universal socket module, 0.075 inch pitch, with 10 pins
	16442B-803	Universal socket module, 0.05 inch pitch, with 10 pins
	16442B-810	Extra pin set (for universal socket module, 10 pins.)
	16442B-811	Extra wire set (mini banana to pin plug, 6 ea.)
	16442B-812	Extra wire set (pin plug to pin plug, 6 ea.)
	16442B-813	Extra wire set (mini banana to mini clip, 6 ea.)
	16442B-814	Extra wire set (mini banana to mini banana, 6 ea.)
	16442B-821	Socket module, 4-pin TO package
	16442B-822	Socket module, 18-pin DIP package
	16442B-823	Extra socket module, 28-pin DIP package
	16442B-890	Extra accessory case
16444A		Accessories for B1500A
	16444A-001	USB keyboard
	16444A-002	USB mouse
	16444A-003	Stylus pen

Model Number	Option Item	Description
16445A		Selector adapter for 16440A
	16445A-001	Control cable (B1500 to 16445A), 1.5 m
	16445A-002	Control cable (B1500 to 16445A), 3.0 m
16493G		Digital I/O connection cable
	16493G-001	1.5 m length
	16493G-002	3 m length
16493J		Interlock cable
	16493J-001	1.5 m length
	16493J-002	3 m length
	16493J-003	5 m length
16493K		Kelvin triaxial cable (B1500 to B1500)
	16493K-001	1.5 m length
	16493K-002	3 m length
16493L		GNDU cable
	16493L-001	1.5 m length
	16493L-002	3 m length
	16493L-003	5 m length
16493M		Triaxial and D-sub cables for ASU
	16493M-001	1.5 m length
	16493M-002	3 m length
16493N		GNDU cable for B2200 Kelvin input
	16493N-001	2 m length
16493P		SPGU output connection cable (SMA to BNC)
	16493P-001	1.5 m length
	16493P-002	3 m length

Model Number	Option Item	Description
16493Q		SPGU-SPGU connection cable (SMA to SMA)
	16493Q-001	8 cm length
16493R		WGFMU Cables and Accessories
	16493R-001	WGFMU-to-RSU cable, 0.6 m
	16493R-002	WGFMU-to-RSU cable, 2.4 m
	16493R-003	WGFMU-to-RSU cable, 3 m
	16493R-004	WGFMU-to-RSU cable, 5 m
	16493R-005	WGFMU-to-RSU cable, 4.4 m
	16493R-006	WGFMU-to-RSU cable, 1.5 m
	16493R-101	SSMC short-open cable for current return path, 50 mm
	16493R-102	SSMC short-open cable for current return path, 75 mm
	16493R-202	SMA-SSMC cable between RSU and DC probe, 200 mm
	16493R-302	SMA-SMA cable between RSU and RF probe, 200 mm
	16493R-801	WGFMU connector adapter (female-female)
	16493R-802	Magnet stand for RSU
	16493R-803	Sync terminal connection cable
16494A		Triaxial cable
	16494A-001	1.5 m length
	16494A-002	3 m length
	16494A-003	80 cm length
	16494A-004	40 cm length
	16494A-005	4 m length
16494B		Kelvin triaxial cable (B1500 to E5250)
	16494B-001	1.5 m length
	16494B-002	3 m length
	16494B-003	80 cm length

Model Number	Option Item	Description
16495F		Connector plate w/ 12×triax., Interlock, GNDU
	16495F-001	Bulkhead feedthrough connectors (female to female)
	16495F-002	Connectors to contacts for soldering
16495G		Connector plate w/ 24×triax., Interlock, GNDU
	16495G-001	Bulkhead feedthrough connectors (female to female)
	16495G-002	Connectors to contacts for soldering
16495H		Connector plate w/ 6×triax., 6×coax., Interlock, GNDU
	16495H-001	Bulkhead feedthrough connectors (female to female)
	16495H-002	Connectors to contacts for soldering
16495J		Connector plate w/ 8×triax., 4×coax., Interlock, GNDU
	16495J-001	Bulkhead feedthrough connectors (female to female)
	16495J-002	Connectors to contacts for soldering
16495K		Connector plate with universal cable holder
	16495K-001	Connector plate with rubber holder
B1510A		High Power Source/Monitor Unit module (HPSMU)
B1511B		Medium Power Source/Monitor Unit module (MPSMU)
B1514A		Medium Current Source/Monitor Unit module (MCSMU)
B1517A		High Resolution Source/Monitor Unit module (HRSMU)
B1520A		Multi Frequency Capacitance Measurement Unit module (MFCMU)
B1525A		Semiconductor Pulse Generator Unit module (SPGU)
B1530A		Waveform Generator/Fast Measurement Unit (WGFMU)
	B1530A-0KN	Self-paced sample program learning kit
B1531A		Remote-sense and Switch Unit (RSU)
B1542A		Pulsed IV package for B1500A/EasyEXPERT

Model Number	Option Item	Description
E5288A		Atto Sense and Switch Unit (ASU)
	E5288A-001	Add triaxial and D-sub cables, 1.5 m
	E5288A-002	Add triaxial and D-sub cables, 3 m
N1253A		Accessories for Digital I/O
	N1253A-100	Digital I/O T-cable
	N1253A-200	Digital I/O BNC Box
N1254A		Accessories
	N1254A-100	GNDU Kelvin Adapter
	N1254A-108	ASU Magnetic Stand
N1255A		2 Channels Connection Box for MCSMU
N1300A		CMU cable
	N1300A-001	1.5 m length
	N1300A-002	3 m length
N1301A		Accessories for CMU
	N1301A-100	SMU CMU Unify Unit (SCUU)
	N1301A-102	SCUU cable, 3 m
	N1301A-110	SCUU magnetic stand
	N1301A-200	Guard Switch Unit (GSWU)
	N1301A-201	GSWU cable, 1.5 m
	N1301A-202	GSWU cable, 3 m

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